AD-753 586

THE SWEM (STRATEGIC WEAPONS EXCHANGE MODELS) ALLOCATION MODEL: VERSION II

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Prepared for:

Department of the Army

December 1972

The SWEM Allocation Model

Version II

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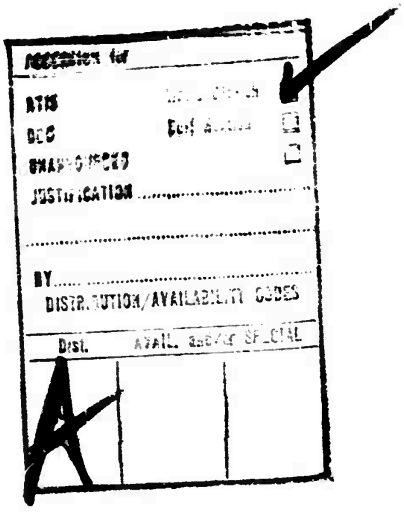

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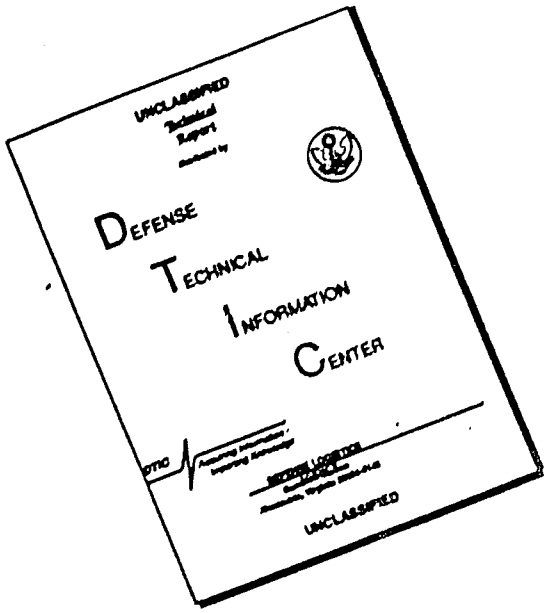

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Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) Research Analysis Corporation Mclean, Virginia 22101	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b GROUP

3 REPORT TITLE

The SWEM Allocation Model - Version II

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final

5 AUTHOR(S) (First name, middle initial, last name)

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6 REPORT DATE December 1972	7a. TOTAL NO. OF PAGES ~~163~~ 164	7b. NO. OF REFS 0
8a CONTRACT OR GRANT NO. DAHC19-69-C-0017 b. PROJECT NO. 012.125 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) RAC-CR-71 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	

10 DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11 SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Deputy Chief of Staff for Military Operations

13 ABSTRACT

The SWEM Allocation Model is a mathematical optimization model which allocates strategic weapons in a two-sided nuclear exchange and provides damage results and specific allocations. The model is useful in defining levels of parity between the nuclear arsenals of two nations. Version II of this model expands the allocation matrix to include attack on defense installations and provides the optimal tradeoff between attack of defense installations, weapon targets (silos) and cities.

This document describes a mathematical optimization model which provides allocations and damage levels in a two-strike nuclear war. It is an extension of an allocation model (Strategic Weapons Exchange Allocation Model-Version I) which has been documented in manuals mentioned in the Introduction. The new allocation model allows attack on defense installations as well as cities and weapon targets, and provides optimal trade-offs in allocation between defense installations, cities, and weapon targets. This document describes the capabilities and limitations of the model, gives the format of the input and output of the model, provides example problems and contains the annotated Fortran listing of the program.

DD FORM 1 NOV 65 1473

Security Classification

RAC

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
strategic weapons allocation model nuclear parity						

TECHNOLOGICAL SYSTEMS GROUP CLIENT REPORT RAC-CR-71 Published December 1972

The SWEM Allocation Model

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FOREWORD

The model described in this document is an extension of one of the Strategic Weapons Exchange Models (SWEM) which have been programmed to aid in decision making concerning the procurement, deployment, and allocation of strategic weapons. As detailed further in the Introduction, these models were documented in a recent series of documents by the Research Analysis Corporation. The document provides the basic information necessary to run the model, but is not intended to be used independently of the other documentation of the SWEM models.

This model, SWEM Allocation Model, Version II, is an extension of the allocation optimization model to include defense installations as targets. The model will be an aid in the decision making process regarding the allocation optimization of offensive strategic nuclear weapons against defense installations. It is useful in defining levels of parity between the nuclear arsenals of two nations and provides the optimum tradeoff between attack of defense installations, weapon targets (silos), and cities.

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Vice President
Technological Systems Group

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Chapter 1

INTRODUCTION

The model described in this document (SWEM Allocation Model - Version II) is another member of the set of Strategic Weapons Exchange Models (SWEM) which have been produced and documented by the Research Analysis Corporation. This model is an extension of the SWEM Allocation Model which was used in the SWEM Second Strike Model (Version II) and documented in the manual, A Planners Guide and Users/Programmer Manual for Strategic Weapons Exchange (SWEM) Second Strike Model - Version II, RAC-CR-43. The model user should also be familiar with the SWEM Allocation Model - Version I which is documented in the manual, The Strategic Weapons Exchange Models Users Manual, RAC-CR-14, and the general description of the SWEM models which is contained in the document, Strategic Weapons Exchange Model Planners Guide, RAC-CR-36. The model uses the same nonlinear mathematical algorithm for solution, the Sequential Unconstrained Minimization Technique (SUMT), as other SWEM models. This algorithm is documented in the manual, A SWEM System/Programmer's Guide to SUMT - Version IV, RAC-CR-34. The present manual is meant to serve as an annex to the above documents and is not self-contained.

This model extends the capability of the SWEM Allocation Model - Version I in several ways. The major change is the inclusion of defense installations as target classes. The model now gives optimal allocation of offensive strategic weapons against city targets, weapon targets (ICBM silos), and the defense installation of each of the city and weapon targets. In addition, this new allocation model which was included in the SWEM second strike model has several features which were not available in the earlier version of the SWEM Allocation Model. These features include:

- More than a single type of each level of defensive weapon: area missile defender, terminal missile defender, bomber interceptor and SAM, can be input into the model.
- Options for the employment of defense against the attack can span the range from a randomly committed defense to a proportional defense which attacks incoming missiles on the basis of damage capability. Thus a range of defense effectiveness can be investigated with the model.
- First strike offensive weapons are designated as countervalue only or countervalue and counterforce. This feature reduces the number of variables in the model and allows more geographical areas or target classes to be included.
- Bombers are allocated optimally instead of on the basis of population.

This manual documents the model changes for the strategic analyst, user, and programmer. The first section contains a description of model characteristics, assumptions, and uses for the strategic analyst interested in applying the model to strategic problems. The mathematical formulation of the model is also provided in App. A. The second section contains for the user a detailed description of the model input, a sample force table with all information needed to run the model, and a sample Fortran code sheet containing the model input from the force table. Output from the model for a series of six sample problems using the sample input data is given in the fourth section.

For the programmer, a Fortran listing of the program that contains extensive comment cards is provided in App. B, together with a partial Fortran glossary which references the most important Fortran variables with their counterpart in the mathematical notation in App. D.

Chapter 2

MODEL CHARACTERISTICS, ASSUMPTIONS, AND USES

Two types of problems arise when considering attacks on defense installations. The problem of the offensive planner is to determine if defense installation should be attacked and if so, which installations should be attacked and at what level in order to achieve his strategic objectives. The second problem is for the defense planner who must deploy defenses geographically and determine the level of defenders at each installation in order to achieve his strategic objectives. This model is designed to study some of the tradeoffs involved in decisions of this type at the strategic rather than the tactical level.

The current scenario of the SWEM Allocation Model does not allow for a direct attack by the first striker on the defensive installations of the second striker. Such attack scenarios are feasible since an attack on defense installations might result in more damage to value targets. This additional damage is caused by the remaining attackers which survive the degradated defenses.

The new model is an optimization model which considers the optimal allocation of offensive strategic weapons in a two-strike nuclear war against city targets, weapon targets, and defense installations. Side one is assumed to have an inventory of different types of offensive weapons which attack target classes of side two which can be weapon classes such as ICBM silos, geographical city regions, or defense installations of each of the weapon or target classes. Side two is then assumed to strike back with all of his remaining weapons on side one cities. Side one weapons can be optimally allocated against side two targets in the model according to a range of criteria. The objective function of the model involves the difference in value damage to the two nations

and the first striker objective can range from maximing damge to side two, to maximing the difference in damage, to minimizing his own damage. Model output includes the damage to both nations, the optimal set of allocations against value targets and defense installations, and many other detailed characteristics of the exchange.

The model takes into account two main effects of the attack on defenses.

1. The attrition of defenders due to attack on their defense installation, thereby allowing more attackers through the defenses.
2. The missiles actually attacking the defense installation are deleted from attack on other targets.

The new model feature allows the user to select up to four side one weapon types which can attack specific types of defense installations of side two. Thus a side one missile type can be chosen to attack side two SAM bases prior to the attack on cities, or a side one missile can be specified to attack hard site defense of ICBMs prior to an attack. The model will determine if the attack on defense will achieve the strategic objectives of side one and what the optimal level of attack would be to achieve these objectives. The model will simultaneously optimize attack on all types of defense installations for each city class or weapon target and the attack on cities and weapons. The model also can handle several different defense installations defending a certain region as well as multiple defense installations of the same type in the same region.

The attack on defense installations is formulated on an expected value basis. Damage curves as a function of the level of attack for each defense installation are calculated based on calculating the probability that a single missile will be reliable, penetrate the defense, and hit the target for each level of attack. The number of surviving defenders free to counteract the attack on values is just the total original number at the defense installation times the probability that a single missile will impact to destroy the targets. Of course, the probability of impacting on target increases the greater the level of attack on the defense installation. These damage

curves are generated inside the program and then an analytic function is fit in order to provide the main optimization routine with the defense damage curves.

The methodology for including attack on defense installation contains the following limitations and assumptions.

1. Single type of offensive weapon can be targeted against a given type of defense installation. The model allows either missiles or bombers to attack any type of defense installation, but only a single type of weapon can attack a given type of installation.

2. The first impacting missile on the target defense installation will destroy the defenders associated with that installation.

3. The geographical regions chosen are non-overlapping and must be the same for each defense installation type.

4. The attack on defenses is one sided in that only the defenses of the second striker are subject to attack.

5. The solutions obtained by the model are not guaranteed to be globally optimal because of the non-convex nature of the problem, thus different standing points may have to be used to obtain the globally optimal solution.

The first assumption is made to reduce the number of allocation variables and does not represent a serious limitation. In general a single type of weapon with high kill probability against a particular defense installation will be chosen to attack. The second assumption indicates that an impacting warhead will destroy either all defenders or the command and control system necessary to target defenses. This assumption is probably valid for all defenses except aircraft with AWACS. In this case the aircraft would simply not be input into the model as being destroyable at the defense installation. The third assumption is the most stringent in the current model. The geographical regions for the model must be the same for each defense type. That is, for each defense type the defense is assumed to operate over the same geographical region. This will usually entail certain compromises with realism in the choice of geographic regions and footprints of the actual weapon system. Attacks against only one type of defense installation, for instance, airbases, can be realistically modeled. In general the compromise will be defense conservative since usually defense regions will

be larger than they actually are. The damage and allocations that come out of the model will generally be defense conservative.

The fourth assumption can be overcome to a certain extent by a series of runs where side one and side two are interchanged to model the situation where both side one and two attack defenses.

The fifth item is not a serious limitation of the model. It means in certain instances, primarily for the cases where the damage difference is being optimized, that more than a single run may have to be made to insure a globally optimal solution. This is usually best done by running different values of the K parameter, say .1, 1.0, 10 instead of only the value of 1.

The model can be used to address either the problems of the offensive planner planning an attack which can include attack on defenses or the defensive planner who must deploy defenses so they are not vulnerable to attack by the offense. Some of the tradeoffs which occur in this type of analysis and which can be studied with the model include:

1. The degree of defense dispersal and the number of defenders at each installation, i.e., the number of missile radars, airfields necessary to make the offense indifferent to whether he does or does not attack the defense.

2. The proper balance of different types of defense, i.e., bomber and missile defense, to defend value targets.

3. The type and proper level of allocation of strategic weapons against defended targets between the value target itself and the defense installation.

In general these types of studies can be carried out with the model by parametrically varying the following model parameters.

1. The area or region of defense effectiveness for defender types.

2. The number of defense installations for value targets and the number of defenders at different installations.

3. The overall level of defense against different types of threats.

One of the limitations of the SWEM models generally is a noninteger weapon allocation to individual silos. Thus less than a single missile can be allocated to a single silo and cause damage. The damage to silos

from an attack is accurate when survival probabilities are large enough to cause at least one missile allocated per silo. However with very small survival probabilities, less than one on one allocation will result and the damage will be overestimated. The current model limits survival probabilities to be > .01 to partially overcome this problem. Thus in the calculation of Sij which is done in subroutine READIN, if Sij comes out to be less than .01, it is set to .01 + Sij. This value of .01 could be adjusted so as to obtain at least one on one allocation of offensive missiles on silos.

Chapter 3

MODEL INPUT

INPUT DATA FOR THE ALLOCATION MODEL

1. First card - SUMT parameter card
2. Next set of cards - Starting point cards
3. Next set of cards - Data for the allocation model
4. Last three cards - SUMT option and additional parameters

Details concerning the groups of cards will be discussed in order. The reader may find it convenient to examine the sample input data contained on the coding sheets in conjunction with the discussion.

1. First card - SUMT parameter card

COLUMNS	01-12	12-24	25-36	37-48	49-60	61-64	65-68	69-72
FORMAT	E12.0	E12.0	E12.0	E12.0	E12.0	I4	I4	I4
NAME OF INPUT	EPSI	RHOIN	THETAO	RATIO	TMMAX	MC	NV	MZ
SUGGESTED VALUE	.01	.05	.00001	2.0	1800.			

where MC = the number of inequality constraints

NV = the number of variables

MZ = 0 or blank

2. Next set of cards - Starting point cards

This set of data contains [NV/6] + 1 cards. For the sample problem NV = 87 and we have 15 cards. The starting point cards have the format 6E12.0. By setting NU1 = 1 (column 60) on the first card after the last starting point card STARTB will select a feasible starting point, thus enabling the user to free himself of this task. A set of [NV/6] + 1 blank cards may then be substituted for the starting point data.

For those prefering to select their own starting points, the information is read in the following order: first the non defense allocations are read in by columns i.e., x(i,1) (i = 1,...,II), x(i,JJ) (i = I + 1,...,II), next the values of the first striker defense allocation variables are read in by rows u(1,k) (k = 1,..., D), u(II,k) (k = 1, ..., D). If D ≤ 0 then there are no allocations of side one weapons against side two defenses.

3. Next set of cards - Data for the allocation model

The input data for the allocation model is read in once per problem. For convenience of reference the input data is discussed in the order it is read in and by the type of data it is.

(3-1) Problem Size and Option Inputs

Format 1315

I II M J JJ K L N D NDEFS IB1 NU1 NU3 NU4 (1st card)

D1 D2 (2nd card)

where

I = total number of side 2 CF targets (ICBMs)

II = total number of side 2 targets (ICBMs + Cities)

M = total number of side 2 weapon types (ICBMs, SLBM, Bombers)

J = total number of side 1 weapon types with CF and CV capability

JJ = total number of side 1 weapon types

K = total number of side 2 defender types

L = total number of side 1 geographic areas

N = total number of side 1 defender types

D = total number of side 2 defender types which can be attacked

NDEFS = side 2 defense allocation doctrine

- ≤ 1 is proportional
- 2 is uniform
- ≥ 3 the user must read in his own

IB1 = side one defense allocation doctrine

$\left\{\begin{array}{l} \leq 1 \text{ is proportional} \\ 2 \text{ is uniform} \\ \geq 3 \text{ the reader must read in his own} \end{array}\right.$

NU1 = If NU1 = 1 a starting feasible point is calculated automatically, otherwise the starting point is read in

NU3 = If NU3 = 1 a printout of the first strikers allocations occurs for every point of the SUMT algorithm

NU4 = The total number of strategies (different ratios of k2/k1) to be considered for a problem set

D1 - The maximum number of types of side 2 defensive weapon types which can be attacked by side one weapon type 1

$0 \leq D1 \leq 4$

D2 = The maximum number of types of side 2 defensive weapon types which can be attacked by side one weapon type 2

$0 \leq D2 \leq 2 \qquad D1 + D2 \leq 4 \text{ and } D1 \geq D2$

(3-2) Damage Curve Fit Parameters and Fractional Populations

Format 10F8.0

$\left\{\begin{array}{ll} A(1),\ldots,A(II\text{-}I) & \text{each line is one card} \\ \bar{A}(1),\ldots,\bar{A}(L) & \\ P(1),\ldots,P(II\text{-}I) & \\ \bar{P}(1),\ldots,\bar{P}(L) & \end{array}\right.$

where

A_i = fitting constants for side 2 populations ($i = 1,\ldots,II\text{-}I$)

$\bar{A}_\ell$ = fitting constants for side 1 populations ($\ell = 1,\ldots,L$)

P_i = fraction of side 2 populations in ith area ($i = 1,\ldots,II\text{-}I$)

$\bar{P}_\ell$ = fraction of side 1 populations in ℓth area ($\ell = 1,\ldots,L$)

(3-3) Side Two Offensive Systems and Single Shot Survival Probabilities Against Side One Defensive Weapon Types

Format 5E8.0,A8

$n_m \quad \bar{r}_m \quad w2_m \quad PSI_m \quad ZN2_m \quad TITLE2_m$

Format 10F8.0

$\bar{P}_{mn} \quad (n = 1,\ldots,N)$

First I side 2 offensive weapon systems (weapons in hard sites)

Format 4E8.0,A6: n_m $\bar{r}_m$ $w2_m$ $ZN2_m$ $TITLE2_m$

10F8.0: $\bar{p}_{mn}$ (n = 1,...,N)

Next M-I side 2 offensive weapon systems

where

n_m = total inventory of side 2 mth type offensive weapon

$\bar{r}_m$ = force reliability of side 2 mth type offensive weapon

$w2_m$ = warhead yield (MT) of side 2 mth type offensive weapon

HSI_m = hardness (P.S.I.) of base (or side 2 mth type offensive weapon (m = 1,...,I)

$ZN2_m$ = number of warheads delivered by side 2 mth type offensive weapon

$TITLE2_m$ = name of side 2 mth type weapon

$\bar{p}_{mn}$ = single shot survival probability of side 2 mth type weapon engaged by side 1 nth type defender (n = 1,...,N)

(3-4) Side One Offensive Systems and Single Shot Survival Probabilities Against Side Two Defensive Weapon Types

Format 7E8.0,A8: m_j r_j e_j wl_j CEP_j FPP_j $ZN1_j$ $TITLE1_j$

10F8.0: p_{jk} (k = 1,...,K)

First J weapons with both CV and CF capability

Format 5E8.0,A8: m_j r_j e_j wl_j $ZN1_j$ $TITLE1_j$

10F8.0: p_{jk} (k = 1,...,K)

Next JJ-J weapons with CV capability only

where

m_j = total inventory of side 1 jth type offensive weapon

r_j = force reliability of side 1 jth type offensive weapon

e_j = number of independently targetable warheads per each side 1 attacker

wl_j = warhead yield per side 1 weapon type j

CEP_j = radius of circle (N. Mi) of error probability .5 for side 1 weapon type j (j = 1,..., J only)

FPP_j = number of cluster warheads for side 1 weapon type j (j = 1,...,J only)

$ZN1_j$ = number of warheads per side 1 weapon type j

$TITLE1_j$ = name of each side 1 jth type weapon

p_{jk} = single shot survival probability of side 1 jth type attacker when engaged by side 2 kth type defender (k = 1,...,K)

(3-5) Side One Offensive Weapon Inventory Which Can Be Used For Other Military Targets (i.e., held back from the first strike)

Format 10F8.0 { uu_j (j = 1, JJ)

where

uu_j = number of each side 1 weapon assigned to other military targets (j = 1,...,JJ)

(3-6) Strategies to be Investigated for the Problem Set (Ratio of (k2/k1))

Format 10F8.0 { RAT(i) = ratio of k2/k1 for case i, i = 1,...,NU4

(3-7) Side One Reliable Defensive Weapons Inventory For Each Side One City Class ℓ (ℓ = 1,L)

Format 10F8.0 { $\bar{d}_{\ell n}$ (n = 1,...,N)

where

$\bar{d}_{\ell n}$ = number of reliable side 1 defenders of side 1 ℓth target (ℓ = 1,...,L)(n = 1,...,N)

(3-8) Side Two Defensive Weapons Systems Force Reliability

Format 10F8.0 { r'_k (k = 1,...K)

where

r'_k = reliability of kth type side 2 defender (k = 1,...,K)

(3-9) Side Two Defensive Weapons Inventory for Side Two Weapons Which Are Not Attacked by Side 1

Note: If D ≤ 0 there is not an attack on side two defensive weapons and all side two defensive weapons inventories are read in at this point.

Format 10F8.0 { For each side two resource i (i = 1,...,II)

d'_{ik} (k = D + 1,...,K)

where

d'_{ik} = number of side 2 defensive weapon type k defending side 2 ith type resource

FOR ATTACK ON DEFENSES ONLY

(3-10) Side One Offensive Weapon Survival Probability Against Side Two Base Defenders

Format 10F8.0 $\{ \bar{S}_k \ (k = 1,\ldots,I)$

where

$\bar{S}_k$ is the survival probability of the side one offensive weapon which attacks side two defenders of type k

(3-11) Detailed Side Two Defense Structure (for defenses which can be attacked)

For each side two defensive weapon type k (k = 1,...,D)

(3-11-1)

Format (13I5) { Read for each side two resource type i (i = 1,...,II)

NBASE, IFIT, LLO, LL1

where

NBASE = total number of defense installation of resource type i

IFIT = 1 if user wants to select points LLO and/or LL1 over which least squares curve fit will be made

LLO = starting point for curve fit (1 unless user overrides)

LL1 = final point for curve fit (the last value for which the expected number of surviving side 2 defenders is less than 1 unless user overrides)

Note: If we chose to place no kth type defenders of a particular resource i a blank card is inserted.

(3-11-2) Defense Installation Information (where applicable NBASE ≥ 1)

For each defense installation associated with defensive weapon type k and resource i

Read

Format (10F8.0) { HARD(ℓ) DCAP(ℓ) ACAP(ℓ) } ℓ = 1,..., NBASE, 1 card per each ℓ

where

HARD(ℓ) = the hardness (P.S.I.) of defense installation ℓ

DCAP(ℓ) = the number of defenders associated with defense installation ℓ

ACAP(ℓ) = the number of defenders of defense installation ℓ

4. Last three cards - SUMT option and additional parameters

CARD 1*	COLUMN	7	14	21	28	35	42	49	56	63	70	77
Format (11I7)	VALUE	3	1	2	1	2	1	1	1 (no sensitivity)**	3	2	1

CARD 2	COLUMN	01 - 12	13 - 24
Format (6E12.0)	VALUE	.01	.00001

CARD 3	COLUMN	7	14
Format (11I7)	VALUE	1	1

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* See RAC-CR-34 for discussion of SUMT (version 4) options.
** See section VIII of RAC-CR-14 for discussion of sensitivity.

USER'S OPTIONS FOR THE ALLOCATION MODEL

The options available to the user can be classified as SUMT options and model options. The SUMT options are discussed in RAC-CR-34. Special SUMT option available for use with the model are discussed in RAC-CR-14 Section VIII.

The model options available to the user are as follows:

1. Option of attacking or not attacking side two defenses.
2. Option of selecting defense allocation doctrines for both sides.
3. Option of selecting strategies (objective) to be considered.
4. Option of having program compute starting point.

Explicit details on how to initiate these options are discussed in the sections (3-1) and (3-6) of Input Data for the Allocation Model.

The choice of strategies is made by selecting the ratio K_2/K_1 of the parameters K_1, K_2 in the objective function $K_1\bar{\beta} - K_2\beta$ as follows:

Ratio K_2/K_1	Objective Function	Strategy
0	$\bar{\beta}$	First striker minimized damage to himself (CF attack)
1	$\bar{\beta}-\beta$	First striker minimizes difference in damage
$> 10^7$	$-\beta$	First striker maximizes damage to side two cities (CV attack)

These values of the ratio represent extreme points of interest when developing "fish-tail" type curves. Ranges from .1 to 100 should be considered when sorting out local solutions particularly for the case when ratio = 1 since the objective function is not globally strictly convex.

SAMPLE INPUT DATA

Tables 1, 2, 3, 4, and 5 contain the force table data necessary for input into the model. Following these tables in Table 6 are Fortran coding sheets containing the correct data input for the model using the data in the force tables.

Table 1

FORCE TABLE FOR SIDE ONE OFFENSIVE

System	Inventory	Force Reliability	Yield Per Warheads (mi)	Warheads Per Carrier	No. of Independently Targetable Warheads	No. of Cluster Warheads	CEP (N. Mi)
ICBMH	850.00	.8000	2.300	1	1	1	.15
ICBME	60.00	.8000	2.200	1	1	1	.35
ICBMG	40.00	.7500	20.000	1	1	1	.25
ICBMI	175.00	.7500	4.000	3(MIRV)	3	1	.25
ICBMJ	100.00	.8000	1.400	6(MIRV)	6	1	.15
ICBMK	175.00	.8000	1.400	6(MIRV)	6	1	.15
ICBMA	70.00	.7500	5.000	1	1		
ICBMB	30.00	.7000	4.000	1	1		
ICBMC	65.00	.8000	1.300	1	1		
ICBMD	75.00	.7500	.500	1	1		
ICBMF	140.00	.7000	2.100	1	1		
SLBMA	30.00	.7500	2.100	1	1		
SLBMB	500.00	.7500	2.300	1	1		
SLBMC	400.00	.7500	1.800	1	1		
BOMBA	425.00	.7500	1.000	2	1		

SINGLE SHOT SURVIVAL PROBABILITIES FOR SIDE ONE OFFENSE VERSUS SIDE TWO DEFENDERS

System	1 Anti-Missile	2 Anti-Missile	3 Anti-Bomber	4 Anti-Bomber	Survival Probability Against Base Defenders 1	2	3	4
ICBMH	.1000	.1000	.9999	.9999	.05	.05	.05	.05
ICBME	.1000	.1000	.9999	.9999				
ICBMG	.1000	.1000	.9999	.9999				
ICBMI	.1000	.1000	.9999	.9999				
ICBMJ	.1000	.1000	.9999	.9999				
ICBMK	.1000	.1000	.9999	.9999				
ICBMA	.1000	.1000	.9999	.9999				
ICBMB	.1000	.1000	.9999	.9999				
ICBMC	.1000	.1000	.9999	.9999				
ICBMD	.1000	.1000	.9999	.9999				
ICBMF	.1000	.1000	.9999	.9999				
SLBMA	.1000	.1000	.9999	.9999				
SLBMB	.1000	.1000	.9999	.9999				
SLBMC	.1000	.1000	.9999	.9999				
BOMBA	.9999	.9999	.2500	.3200				

Table 2

FORCE TABLE FOR SIDE TWO OFFENSE

System	Inventory	Force Reliability	Warhead Yield (MT)	No. of Warheads	Hardness (P.S.I.)
ICMB3	600.00	.7800	.150	3	300.00
ICBM2	400.00	.8000	1.000	1	300.00
ICBM1	30.00	.7400	6.000	1	300.00
SLBM1	150.00	.6200	.200	3	
SLBM2	375.00	.6000	.020	10	
BOMB1	40.00	.7200	10.000	10	
BOMB2	125.00	.7200	1.000	2	
BOMB3	40.00	.7200	.150	20	
BOMB4	40.00	.7200	.150	20	
BOMB5	50.00	.7200	.150	4	

SINGLE SHOT SURVIVAL PROBABILITIES FOR SIDE TWO OFFENSE VERSUS SIDE ONE DEFENDERS

System	1 Anti-Missile	2 Anti-Missile	3 Anti-Bomber	4 Anti-Bomber
ICMB3	.1500	.2800	.9999	.9999
ICMB2	.1500	.2800	.9999	.9999
ICMB1	.1500	.2800	.9999	.9999
SLBM1	.1500	.2800	.9999	.9999
SLBM2	.1500	.2800	.9999	.9999
BOMB1	.9999	.9999	.0800	.0900
BOMB2	.9999	.9999	.0800	.0900
BOMB3	.9999	.9999	.0800	.0900
BOMB4	.9999	.9999	.0800	.0900
BOMB5	.9999	.9999	.0800	.0900

Table 3

FORCE TABLE FOR SIDF TWO DEFENSE

Target Class Defended (Counterforce)

Side Two Defender Type	ICBM3				ICBM2				ICMB1			
1 Anti-Missile	No. of Defense Installations 2				No. of Defense Installations 2				No. of Defense Installations 2			
	Base No.	Hard-ness (PSI)	Dfdrs. of Base	Dfdrs. at Base	Base No	Hard-ness (PSI)	Dfdrs. of Base	Drdrs. at Base	Base No.	Hard-ness (PSI)	Dfdrs. of Base	Dfdrs. at Base
	1	50	55	322	1	50	54	264	1	50	40	121
	2	50	50	302	2	50	47	144	2	50	40	121
2 Anti-Missile	No. of Defense Installations 0				No. of Defense Installations 0				No. of Defense Installations 0			
3 Anti-Bomber	No. of Defense Installations 0				No. of Defense Installations 0				No. of Defense Installations 0			
4 Anti-Bomber	No. of Defense Installations 0				No. of Defense Installations 0				No. of Defense Installations 0			

Table 4

FORCE TABLE FOR SIDE TWO DEFENSE

Target Class Defended (Countervalue)

Side Two Defender Type	City Class 1				City Class 2				City Class 3			
1 Anti-Missile	No. of Defense Installations 7				No. of Defense Installations 13				No. of Defense Installations 3			
	Base No.	Hardness (PSI)	Dfdrs. of Base	Dfdrs. at Base	Base No.	Hardness (PSI)	Dfdrs. of Base	Dfdrs. at Base	Base No.	Hardness (PSI)	Dfdrs. of Base	Dfdrs. at Base
	1	50	21	84	1	50	16	48	1	50	38	115
	2	50	78	312	2	50	52	148	2	50	55	225
	3	50	12	48	3	50	15	44	3	50	10	30
	4	50	13	52	4	50	58	177				
	5	50	80	358	5	50	20	60				
	6	50	18	72	6	50	16	48				
	7	50	8	32	7	50	10	30				
					8	50	44	134				
					9	50	36	109				
					10	50	19	56				
					11	50	24	74				
					12	50	20	62				
					13	50	15	45				
2 Anti-Missile	No. of Defense Installations 0				No. of Defense Installations 0				No. of Defense Installations 0			

Table 4 (Cont'd.)

Side Two Defender Type	City Class 1				City Class 2				City Class 3			
3 Anti-Bomber	No. of Defense Installations 1				No. of Defense Installations 1				No. of Defense Installations 1			
	Base No.	Hardness (PSI)	Dfdrs. of Base	Dfdrs. at Base	Base No.	Hardness (PSI)	Dfdrs. of Base	Dfdrs. at Base	Base No.	Hardness (PSI)	Dfdrs. of Base	Dfdrs. at Base
	1	50	40	200	1	50	50	300	1	50	40	200
4 Anti-Bomber	No. of Defense Installations 3				No. of Defense Installations 3				No. of Defense Installations			
	Base No.	Hardness (PSI)	Dfdrs. of Base	Dfdrs. at Base	Base No.	Hardness (PSI)	Dfdrs. of Base	Dfdrs. at Base	Base No.	Hardness (PSI)	Dfdrs. of Base	Dfdrs. at Base
	1	50	35	200	1	50	20	100	1	50	20	100
	2	50	20	50	2	50	25	150	2	50	15	50
	3	50	20	100	3	50	15	50	3	50	20	75

FORCE RELIABILITY OF SIDE TWO DEFENDER TYPES

Type 1 - .95 Type 2 - .95 Type 3 - .95 Type 4 - .95

Table 5

FORCE TABLE FOR SIDE ONE DEFENSE

Side One Defender Type	Inventory of Reliable Defenders Target Class Defended 1
1 Anti-Missile	450
2 Anti-Missile	375
3 Anti-Bomber	200
4 Anti-Bomber	400

Table 6

PUNCHED INPUT TO THE MODEL

6400

SYMBOLIC AND FORTRAN CODING SHEET

RAC — SHEET 1 OF 9

NAME | DATE | PROBLEM NO. | PHONE | PROGRAM TITLE | PUNCH 73–80 ☐ Yes ☐ No

STATEMENT NUMBER / SYMBOL | CONT. | FORTRAN STATEMENT → OPERATION | OPERANDS | COMMENTS → | FORTRAN CHECK ☐ | SYMBOLIC CHECK ☐ | IDENT. | PG. | LINE

```
C-CØDED DATA IPUT --- CØMMENT CARDS SHØULD BE DISCARDED FRØM ACTUAL DATA ---
C---SEE DESCRIPTIØN ØF INPUT DATA FØR DETAILS ---
C--(1)--SUMT PARAMETER CARD ---
       1.E-2       .05         1.E-6       2.E+0    1200.     15  87   0
C--(2)--STARTING PØINT CARDS --- THIS SET ØF DATA CØNSISTS ØF 15 CARDS ---
       1.E-2       1.E-2       1.E-2     5.24E+1     3.18E+1     1.85E+1
       1.E-2       1.E-2       1.E-2     1.05E+1     6.38E+0     3.71E+0
       1.E-2       1.E-2       1.E-2     1.31E+1     7.98E+0     4.63E+0
       1.E-2       1.E-2       1.E-2     2.45E+1     1.49E+1     8.68E+0
       1.E-2       1.E-2       1.E-2     3.07E+1     1.87E+1     1.08E+1
       1.E-2       1.E-2       1.E-2     2.62E+1     1.59E+1     9.26E+0
     8.61E+0     5.24E+0     3.04E+0     4.02E+0     2.45E+0     1.42E+0
     1.07E+1     6.52E+0     3.79E+0     1.00E+1     6.11E+0     3.55E+0
     1.87E+1     1.14E+1     6.62E+0     8.61E+0     5.24E+0     3.04E+0
     7.17E+1     4.36E+1     2.53E+1     5.73E+1     3.48E+1     2.02E+1
     5.02E+1     3.05E+1     1.77E+1     1.00E-2     1.00E-2     1.00E-2
     1.00E-2     1.00E-2     1.00E-2     1.00E-2     1.00E-2     1.00E-2
     1.00E-2     1.00E-2     1.00E-2     5.24E+1     5.24E+1     5.24E+1
     5.24E+1     3.18E+1     3.18E+1     3.18E+1     3.18E+1     1.85E+1
     1.85E+1     1.85E+1     1.85E+1
```

Table 6 (Contd)

RAC

6400

SYMBOLIC AND FORTRAN CODING SHEET

SHEET 2 OF 9

NAME	DATE	PROBLEM NO.	PHONE	PROGRAM TITLE	PUNCH 73–80 ☐ Yes ☐ No

STATEMENT NUMBER / SYMBOL | CONTINUATION | FORTRAN STATEMENT → | FORTRAN CHECK ☐ | IDENT. | PG. | LINE

OPERATION | OPERANDS | COMMENTS → | SYMBOLIC CHECK ☐

```
C   ---DATA FOR THE ALLOCATION MODEL
C   ---(3-1)-PROBLEM SIZE AND OPTION CARDS---
    3          6        10        6        15        4        1        4        4        1        1        1        1
    4          0
C   ---(3-2)-DAMAGE CURVE FIT PARAMETERS AND FRACTIONAL POPULATIONS
.0824225.092552 .127676
        .145
    .51         .31       .18
    1.0
C   ---(3-3)-SIDE TWO OFFENSIVE SYSTEMS AND SINGLE SHOT SURVIVAL PROBABILITIES
C   ---AGAINST SIDE ONE DEFENSIVE WEAPON TYPES
    600.        .78       .15       300.      3.      ICBM3
        .15     .28       .9999     .9999
    400.        .8        1.        300.      1.      ICBM2
        .15     .28       .9999     .9999
    30.         .74       6.        300.      1.      ICBM1
        .15     .28       .9999     .9999
    150.        .62       .2        3.        SLBM1
        .15     .28       .9999     .9999
    375.        .6        .02       10.       SLBM2
        .15     .28       .9999     .9999
    40.         .72       10.       10.       BOMB1
  .9999 .9999   .08       .09
```

Table 6 (Contd)

RAC

6400
SYMBOLIC AND FORTRAN CODING SHEET

SHEET 3 OF 9

NAME | DATE | PROBLEM NO. | PHONE | PROGRAM TITLE | PUNCH 73–80 ☐ Yes ☐ No

STATEMENT NUMBER / SYMBOL | FORTRAN STATEMENT → OPERATION | OPERANDS | COMMENTS → | FORTRAN CHECK ☐ | SYMBOLIC CHECK ☐ | IDENT. | PG. | LINE

```
C---(13-3)  CØNTINUED
   125.   .72      1.       1.      BØMD2
   .9999    .9999     .08       .09
    40.   .72     .15      20.      BØMB3
   .9999    .9999     .08       .09
    40.   .72     .15      20.      BØMB4
   .9999    .9999     .08       .09
    50.   .72     .15       4.      BØMB5
   .9999    .9999     .08       .09

C---(13-4)-SIDE ØNE ØFFENSIVE SYSTEMS AND SINGLE SHØT SURVIVAL PRØBABILITIES
C------AGAINST SIDE TWØ DEFENSIVE WEAPØN TYPES
   850.   .8       1.      2.3       .15      1.      1.     CBMH
    .1    .1       .9999   .9999
    60.   .8       1.      2.2       .35      1.      1.    ICBME
    .1    .1       .9999   .9999
    40.   .75      1.      20.       .25      1.      1.    ICBMG
    .1    .1       .9999   .9999
   175.   .75      3.      4.        .25      1.      3.    ICBMI
    .1    .1       .9999   .9999
   100.   .8       6.      1.4       .15      1.      6.    ICBMJ
    .1    .1       .9999   .9999
   175.   .8       6.      1.4       .15      1.      6.    ICBMK
    .1    .1       .9999   .9999
    70.   .75      1.      6.       1.      ICBMA
    .1    .1       .9999   .9999
```

Table 6 (Contd)

6400

SYMBOLIC AND FORTRAN CODING SHEET

RAC

SHEET 4 OF 9

NAME	DATE	PROBLEM NO.	PHONE	PROGRAM TITLE	PUNCH 73–80 ☐ Yes ☐ No

STATEMENT NUMBER / SYMBOL (cols 1–6) · FORTRAN STATEMENT / OPERATION / OPERANDS / COMMENTS (cols 7–72) · FORTRAN CHECK ☐ · SYMBOLIC CHECK ☐ · IDENT. / PG. / LINE (cols 73–80)

```
C--(3-4)  CØNTINUED
   30.    .7     1.      4.       1.    ICBMB
    .1     .1      .9999   .9999
   65.    .8     1.      1.3      1.    ICBMC
     1     .1      .9999   .9999
   75.    .75    1.       .5      1.    ICBMD
    .1     .1      .9999   .9999
  140.    .7     1.      2.1      1.    ICBMF
    .1     .1      .9999   .9999
   30.    .75    1.      2.1      1.    SLBMA
    .1     .1      .9999   .9999
  500.    .75    1.      2.3      1.    SLBMB
    .1     .1      .9999   .9999
  400.    .75    1.      1.8      1.    SLBMC
    .1      1      .9999   .9999
   425.   .75    1.      1.       2.    BØMBA
   .9999  .9999         .25         .32

C--(3-5)-SIDE ØNE ØFFENSIVE INVENTØRY USED FØR ØTHER TARGETS (I.E. HELD BACK)-
   100.    30.      40.    100.   12.    100.    40.     15.     30.    40.
    70.    0.     250.     200.   250.

C--(3-6)-STRATEGIES TØ BE INVESTIGATED (RATIØ ØF K2/K1)
   1.E+8
```

Table 6 (Contd)

RAC

6400

SYMBOLIC AND FORTRAN CODING SHEET

SHEET 5 OF 9

NAME | DATE | PROBLEM NO. | PHONE | PROGRAM TITLE | PUNCH 73–80 ☐ Yes ☐ No

STATEMENT NUMBER | CONT | FORTRAN STATEMENT → | FORTRAN CHECK ☐ | IDENT. | PG. | LINE

SYMBOL | OPERATION | OPERANDS | COMMENTS → | SYMBOLIC CHECK ☐

```
C  --(3-7)-SIDE ØNE RELIABLE DEFENSIVE WEAPØNS SYSTEMS INVENTØRY FØR PØPULATIØN
C  ----- -CLASS L
     450.    375.      200.      400.

C  --(3-8)-SIDE TWØ DEFENSIVE SYSTEMS FØRCE RELIABILITY --
     .95      .95       .95       .95

C  --(3-9)-SIDE TWØ DEFENSIVE WEAPØNS INVENTØRY FØR SIDE TWØ WEAPØNS WHICH ARE
C  ------NØT ATTACKED BY SIDE ØNE -- NØ DATA READ IN HERE FØR THIS PROBLEM ---

C  --(3-10)-SIDE ØNE ØFFENSIVE WEAPØN SURVIVAL PROBABILITY AGAINST SIDE TWØ
C  ------DEFENSE INSTALLATIØN DEFENDERS ---
     .05      .05       .05       .05

C  --(3-11)-DETAILED SIDE TWØ DEFENSE STRUCTURE (FØR DFFENSES WHICH CAN BE
C  ------ATTACKED). READ FØR EACH SIDE TWØ DEFENSIVE WEAPØN TYPE K WHERE K
C  ------RANGES FROM 1 TØ THE TØTAL NO. ØF DEFENSIVE WEAPØN TYPES WHICH CAN BE
C  ------ATTACKED
C  --(3-11-1)-SIDE TWØ RESØURCE 1 NØ ØF DEFENSE INSTALLATIØNS
     21
C  --(3-11-2)-SIDE TWØ DEFENSE INSTALLATIØN INFØRMATIØN
     50.    322.      55.
     50.    302.      50.
```

Table 6 (Contd)

RAC

6400

SYMBOLIC AND FORTRAN CODING SHEET

SHEET 6 OF 9

NAME | DATE | PROBLEM NO. | PHONE | PROGRAM TITLE | PUNCH 73–80 ☐ Yes ☐ No

STATEMENT NUMBER | CONT | FORTRAN STATEMENT → | FORTRAN CHECK ☐ | IDENT. | PG. | LINE

SYMBOL | OPERATION | OPERANDS | COMMENTS → | SYMBOLIC CHECK ☐

```
C  --(3-11-1)    RESØURCE 2 , DEFENSIVE WEAPØN TYPE 1
     2
C  --(3-11-2)
     50.    264.     54.
     50.    144.     47.
C  --(3-11-1)    RESØURCE 3 , DEFENSIVE WEAPØN TYPE 1
     2
C  --(3-11-2)
     50.    121.     40.
     50.    121.     40.
C  --(3-11-1)    RESØURCE 4 , DEFENSIVE WEAPØN TYPE 1
     7
C  --(3-11-2)
     50.     84.     21.
     50.    312.     18.
     50.     48.     12.
     50.     52.     13.
     50.    358.     80.
     50.     72.     18.
     50.     32.      8.
C  --(3-11-1)    RESØURCE 5 , DEFENSIVE WEAPØN TYPE 1
    13
C  --(3-11-2)
     50.     48.     16.
     50.    148.     52.
     50.     44.     15.
```

Table 6 (Contd)

RAC

6400
SYMBOLIC AND FORTRAN CODING SHEET

SHEET 7 OF 9

NAME | DATE | PROBLEM NO. | PHONE | PROGRAM TITLE | PUNCH 73–80 ☐ Yes ☐ No

STATEMENT NUMBER | CONTINUATION | FORTRAN STATEMENT → | FORTRAN CHECK ☐ | IDENT. | PG. | LINE

SYMBOL | OPERATION | OPERANDS | COMMENTS → | SYMBOLIC CHECK ☐

```
C  --(3-11-2)   CONTINUED
     50.   177.    58.
     50.   69.    20.
     50.   48.    16.
     50.   30.    10.
     50.   134.    44.
     50.   109.    36.
     50.   56.    19.
     50.   74.    24.
     50.   62.    20.
     50.   45.    15.
C  --(3-11-1)    RESOURCE 6, DEFENSIVE WEAPON TYPE 1
     3
C  --(3-11-2)
     50.   115.    38.
     50.   225.    55.
     50.   30.    10.
C  --(3-11-1)    RESOURCE 1, DEFENSIVE WEAPON TYPE 2
     BLANK CARD
C  --(3-11-1)    RESOURCE 2, DEFENSIVE WEAPON TYPE 2
     BLANK CARD
C  --(3-11-1)    RESOURCE 3, DEFENSIVE WEAPON TYPE 2
     BLANK CARD
C  --(3-11-1)    RESOURCE 4, DEFENSIVE WEAPON TYPE 2
     BLANK CARD
C  --(3-11-1)    RESOURCE 5, DEFENSIVE WEAPON TYPE 2
```

Table 6 (Contd)

RAC

6400

SYMBOLIC AND FORTRAN CODING SHEET

SHEET 8 OF 9

NAME | DATE | PROBLEM NO. | PHONE | PROGRAM TITLE | PUNCH 73–80 ☐ Yes ☐ No

STATEMENT NUMBER / SYMBOL | Cont | FORTRAN STATEMENT → | FORTRAN CHECK ☐ | IDENT. | PG. | LINE

OPERATION | OPERANDS | COMMENTS → | SYMBOLIC CHECK ☐

```
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
      BLANK CARD
C  - -(3-11-1)    RESOURCE 6,DEFENSIVE WEAPON TYPE 2
      BLANK CARD
C  - -(3-11-1)    RESOURCE 1,DEFENSIVE WEAPON TYPE 3
      BLANK CARD
C  - -(3-11-1)    RESOURCE 2,DEFENSIVE WEAPON TYPE 3
      BLANK CARD
C  - -(3-11-1)    RESOURCE 3,DEFENSIVE WEAPON TYPE 3
      BLANK CARD
C  - -(3-11-1)    RESOURCE 4,DEFENSIVE WEAPON TYPE 3
     1
C  - -(3-11-2)
   50.   2000.   40.
C  - -(3-11-1)    RESOURCE 5,DEFENSIVE WEAPON TYPE 3
     1
C  - -(3-11-2)
   50.   3000.   50.
C  - -(3-11-1)    RESOURCE 6,DEFENSIVE WEAPON TYPE 3
     1
C  - -(3-11-2)
   50.   2000.   40.
C  - -(3-11-1)    RESOURCE 1,DEFENSIVE WEAPON TYPE 4
      BLANK CARD
C  - -(3-11-1)    RESOURCE 2,DEFENSIVE WEAPON TYPE 4
      BLANK CARD
C  - -(3-11-1)    RESOURCE 3,DEFENSIVE WEAPON TYPE 4
```

Table 6 (Contd)

RAC

6400

SYMBOLIC AND FORTRAN CODING SHEET

SHEET 9 OF 9

NAME | DATE | PROBLEM NO. | PHONE | PROGRAM TITLE | PUNCH ☐ Yes 73–80 ☐ No

STATEMENT NUMBER | CONTINUE | FORTRAN STATEMENT → | FORTRAN CHECK ☐ | IDENT. | PG. | LINE

SYMBOL | OPERATION | OPERANDS | COMMENTS → | SYMBOLIC CHECK ☐

```
      BLANK CARD
C     (13-11-1)   RESOURCE 4, DEFENSIVE WEAPON TYPE 4
     3
C     (3-11-2)
     50.      200.      35.
     50.       50.      20.
     50.      100.      20.
C     (13-11-1)   RESOURCE 5, DEFENSIVE WEAPON TYPE 4
     3
C     (3-11-2)
     50.      100.      20.
     50.      150.      25.
     50.       50.      15.
C     (13-11-1)   RESOURCE 6, DEFENSIVE WEAPON TYPE 4
     3
C     (3-11-2)
     50.      100.      20.
     50.       50.      15.
     50.       75.      20.

C     (4)--  LAST THREE CARDS- SUMT OPTION AND ADDITIONAL PARAMETER CARDS
C     SEE RAC-CR-34 FOR DISCUSSION OF SUMT (VERSION 4) OPTIONS.---
C     SEE SECTION VIII OF RAC-CR-14 FOR DISCUSSION OF SENSITIVITY.---
     3          1          2          1          2          1          1          1          2          1
     .01                .00001
     1          1
```

Chapter 4

MODEL OUTPUT AND SAMPLE PROBLEM

The output for the allocation optimization model can be classified as follows:

(1) Total damage to each side

(2) Side one counterforce strike characteristics

(3) Side one countervalue strike characteristics

(4) Side one counterdefense strike characteristics (when applicable)

(5) Side two second strike characteristics

The output is fairly self-explanatory and reference to the output given in next section is suggested.

TOTAL DAMAGE TO EACH SIDE

The damage summed over all population classes of each side is printed--first side one, then side two.

SIDE ONE COUNTERFORCE STRIKE CHARACTERISTICS

The attack by each side one counterforce missile type on each side two ICBM type is characterized in the following fashion:

(a) Number of each side one missile allocated against each side two ICBM.

(b) Number of each side one missile arriving over each side two ICBM type.

(c) Number of warheads from each side one missile type arriving over each side two ICBM type.

(d) Number of warheads from each side one missile type impacting on each side two ICMB type.

(e) Number of warheads from each side one missile type impacting on each ICBM silo.

(f) Survival probability of each side two ICBM attack by each side one missile type.

SIDE ONE COUNTERVALUE STRIKE CHARACTERISTICS

The attack by each side one countervalue weapon type on each side two population class is characterized as follows:

(a) Number of each side one countervalue weapon allocated against each side two population class.

(b) Number of each side one countervalue weapon arriving over each side two population class.

(c) Number of each side one countervalue weapon impacting on each side two population class.

(d) Number of 1 MT equivalents from each side one countervalue weapon impacting on each side two population class.

SIDE ONE COUNTERDEFENSE STRIKE CHARACTERISTICS

When the option of attacking side two's defenses is used the following information is provided:

(a) Total number of side one weapons allocated against each side two defender type by resource defended.

(b) Total number of side one weapons arriving over each side two defender type by resource defended.

(c) Original number of side two defenders of each type before side one's attack.

(d) Number of side two defenders of each type one by resource defended surviving side one's attack.

SIDE TWO SECOND STRIKE CHARACTERISTICS

The second strike by side two against side one's population classes is characterized as follows:

(a) Number of side two offensive weapons of each type before side one's counterforce strike.

(b) Number of side two offensive weapons of each type surviving side one's counterforce strike.

(c) Number of side two offensive weapons of each type arriving over side one's population classes.

(d) Number of side two offensive weapons of each type impacting on each of side one's population classes.

(e) Number of 1 MT equivalents delivered by each side two weapon type on each of side one's population classes.

SAMPLE PROBLEMS

The following set of problems is presented both as illustrative of the model capability and to familiarize the users with the model output.

The nuclear arsenal and level of defense for two nations is given. The problem is to derive the optimal set of allocations and the resultant damages in a two-strike nuclear war under various scenarios. In particular, a comparison is to be made of the different damages and allocations under two sets of assumptions:

a. side one (first strike) is allowed to attack and destroy the defenses of side two.

b. side one is not allowed to attack and destroy the defenses of side two.

Scenario:

A two strike war is assumed with side one attacking side two with a specified portion of his input arsenal, and side two striking back with all surviving weapons. The target structure of side two is divided into six different classes of targets: three city classes and three ICBM

weapon classes. The city classes are aggregated geographically into an Eastern, Midwestern, and Western region with the division roughly along the 85 and 105 axes. The three weapon targets are hardened ICBM silos. The defense of each target is assumed independent of other targets -- no overlap. The level of defense of target class is given below.

Target class	Level of missile defense	No. of missile defense sites	Level of bomber defense	No. of bomber defense sites
ICBM3	624	2	0	0
ICBM2	408	2	0	0
ICBM1	242	2	0	0
East	958	7	550	4
Midwest	1035	13	600	4
West	370	3	425	4

For the first set of cases run, side one has the option of attacking the defensive sites of each target class before attacking the target in each case, or of directly attacking the targets without first attacking the defenses. If the defenses are attacked, he must pay the price of the number of missiles required to destroy the defenses. On the other hand, if the defenses are not destroyed, part of his force is attrited by the defense. For the second set of cases run, no attack on defense was allowed.

For each option, three different cases have been run corresponding to an attack by side one maximizing damage on the cities of side two (countervalue), an attack which would minimize the damage to side one (counterforce), and an attack which minimized the difference in damage between the two nations.

The entire input arsenal and characteristics are given first, then the curve fits for attack on defenses, and finally the output for the six cases in the following order:

Attack on defenses option	Objective
Yes	Max damage side two
Yes	Min damage side one
Yes	Max difference in damage

No	Max damage side two
No	Min damage side one
No	Max difference in damage

In the output to the cases, the following numbering scheme is given to the targets and defender types.

Target class	Side two resource
1	ICBM3
2	ICBM2
3	ICBM1
4	City class (East)
5	City class (Midwest)
6	City class (West)

Defender number	Defender type
1	Anti-missile
2	Anti-missile
3	Anti-bomber
4	Anti-bomber

INPUT DATA

**********STRATEGIC WEAPONS EXCHANGE MODELS (SWEM) **********

ALLOCATION OPTIMIZATION MODEL

**INPUT CONDITIONS FOR THIS RUN **

ATTACK ON DEFENSES OPTION USED

NDEFS 1 IB1= 1 NU1=-0 NU3=-0 NU4= 1

SIDE 2 -- 3 OF TARGETS 6 TARGETS 10 WEAPON TYPES 4 DEFENDER TYPES

SIDE 1 -- 6 OF + OW WEAPON TYPES 1 GEOGRAPHIC AREAS 15 WEAPON TYPES 4 DEFENDER TYPES

4 4 0

FITTING CONSTANTS FOR SIDE 2 POPULATION
.0824 .0926 .1277

Side two population divided into three areas. These are K factors.

FITTING CONSTANTS FOR SIDE 1 POPULATION
.1450

Side one population is one geographical region.

FRACTION OF SIDE 2 POPULATION IN ITH AREA
.5100 .3100 .1800

Percentage of population in East, Midwest, West respectively

FRACTION OF SIDE 1 POPULATION IN ITH AREA
1.0000

FORCE STRUCTURE AND WEAPONS CHARACTERISTICS

****

OFFENSIVE SYSTEMS

SIDE TWO

TYPE	SYSTEM	INVENTORY	FORCE REL.	WARHEAD YIELD	NO. OF WH	P.S.I.
1	ICBM3	600.00	.7800	.150	3	300.00
2	ICBM2	400.00	.8000	1.000	1	300.00
3	ICBM1	30.00	.7400	6.000	1	300.00
4	SLBM1	150.00	.6200	.200	3	
5	SLBM2	375.00	.6500	.020	10	
6	BOMB1	40.00	.7200	10.000	10	
7	BOMB2	125.00	.7200	1.000	2	
8	BOMB3	40.00	.7200	.150	20	
9	BOMB4	40.00	.7200	.150	20	
10	BOMB5	50.00	.7200	.150	4	

These first three weapons are the counterforce targets for side one

SIDE ONE

TYPE	SYSTEM	INVENTORY	FORCE REL.	WARHEAD YIELD	NO. OF WH	NO. IND. TAR. WH	NO. CLUSTER WH	CEP
1	ICBMH	950.00	.8000	2.300	1	1	1	.15
2	ICBME	60.00	.8000	2.200	1	1	1	.35
3	ICBMG	40.00	.7500	20.000	1	1	1	.25
4	ICBMI	175.00	.7500	4.000	3	3	1	.25
5	ICBMJ	100.00	.8000	1.400	6	6	1	.15
6	ICBMK	175.00	.8000	1.400	6	6	1	.15
7	ICBMA	70.00	.7500	5.000	1	1		
8	ICBMB	30.00	.7000	4.000	1	1		
9	ICBMC	65.00	.8000	1.300	1	1		
10	ICBMD	75.00	.7500	.500	1	1		
11	ICBMF	140.00	.7000	2.100	1	1		
12	SLBMA	30.00	.7500	2.100	1	1		
13	SLBMB	500.00	.7500	2.300	1	1		
14	SLBMC	400.00	.7500	1.800	1	1		
15	BOMBA	425.00	.7500	1.000	2	1		

The first six weapons are both counterforce and countervalue

The last nine are countervalue only

SINGLE SHOT SURVIVAL PROBABILITIES (SIDE TWO ICBMS VS SIDE ONE MISSILES) ***

SIDE TWO ICBMS (DOWN) — SIDE ONE MISSILES (ACROSS)

	ICBMH	ICBME	ICBMG	ICBMI	ICBMJ	ICBMK
ICBM3	.0104	.2525	.0100	.0180	.0139	.0139
ICBM2	.0104	.2525	.0100	.0180	.0139	.0139
ICBM1	.0104	.2525	.0100	.0180	.0139	.0139

A lower limit of .01 has been placed on the survival probability of side two silos

SINGLE SHOT SURVIVAL PROBABILITIES (SIDE TWO OFFS. VS SIDE ONE DEFORS.) ***

SIDE TWO OFFS. (DOWN) — SIDE ONE DEFORS. (ACROSS)

	1	2	3	4
ICBM3	.1500	.2800	.9999	.9999
ICBM2	.1500	.2800	.9999	.9999
ICBM1	.1500	.2800	.9999	.9999
SLBM1	.1500	.2800	.9999	.9999
SLBM2	.1500	.2800	.9999	.9999
BOMB1	.9999	.9999	.0800	.0900
BOMB2	.9999	.9999	.0800	.0900
BOMB3	.9999	.9999	.0800	.0900
BOMB4	.9999	.9999	.0800	.0900
BOMB5	.9999	.9999	.0800	.0900

These numbers give the defense interaction survival probability.

Defense type 1 and 2 is missile defense

Defense type 3 and 4 is bomber defense

so ICBM3 has a .15 chance of surviving an encounter with Defense type 1

SINGLE SHOT SURVIVAL PROBABILITIES (SIDE ONE ICBMS VS SIDE TWO DEFORS.) ***

SIDE ONE ICBMS (DOWN) — SIDE TWO DEFORS. (ACROSS)

	1	2	3	4
ICBMH	.1000	.1000	.9999	.9999
ICBME	.1000	.1000	.9999	.9999
ICBMG	.1000	.1000	.9999	.9999
ICBMI	.1000	.1000	.9999	.9999
ICBMJ	.1000	.1000	.9999	.9999
ICBMK	.1000	.1000	.9999	.9999
ICBMA	.1000	.1000	.9999	.9999
ICBMB	.1000	.1000	.9999	.9999
ICBMC	.1000	.1000	.9999	.9999
ICBMD	.1000	.1000	.9999	.9999
ICBMF	.1000	.1000	.9999	.9999
SLBMA	.1000	.1000	.9999	.9999
SLBMB	.1000	.1000	.9999	.9999
SLBMC	.1000	.1000	.9999	.9999
BOMBA	.9999	.9999	.2500	.3200

Same interpretation as above

This is the inventory of side one weapons of each type withheld from the attack

NUMBER OF EACH SIDE 1 WEAPON ASSIGNED TO OTHER MILITARY TARGETS

100.0000	30.0000	40.0000	100.0000	12.0000	100.0000	40.0000	15.0000	30.0000	40.0000
70.0000	0.0000	250.0000	200.0000	250.0000					

DEFENSE DAMAGE CURVE DATA

DEFENSIVE SYSTEMS

SIDE ONE

NUMBER OF RELIABLE SIDE 1 DEFENDERS OF SIDE 1 LTH TARGET
450.0000 375.0000 200.0000 400.0000

Inventory of side one defenders

SIDE TWO

RELIABILITY OF KTH TYPE SIDE 2 DEFENDER
.9500 .9500 .9500 .9500

SURVIVAL PROB. OF SIDE ONE OFFS. VS. BASE DEFDRS.
.0500 .0500 .0500 .0500

This section gives the defense characteristics of side two and the damage curves for attacking defenses.

1 1

DEF. WEAP. TYPE 1 REGION OR CITY CLASS DEFENDED 1 NO. OF BASES DEFENDED BY WEAP. TYPE 2

BASE NO.	HARDNESS(PSI)	NO. OF DEFDRS. OF BASE	NO. DEFDRS. AT BASE	DEFENDED BASE SURVIVAL PROB.	UNDEFENDED BASE SURVIVAL PROB.
1	50.00	55.0	322.0	.9025	.0000
2	50.00	50.0	302.0	.9025	.0000

EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE

NO. ATTACKERS	EXP. NO. SURV.	CURVE FIT VALUE
1	592.60	592.79
2	563.16	563.14
3	534.83	534.98
4	508.25	508.22
5	482.68	482.81
6	458.70	458.66
7	435.62	435.72
8	413.97	413.93
9	393.15	393.23
10	373.61	373.56
11	354.81	354.88
12	337.18	337.13
13	320.22	320.27
14	304.31	304.25
15	289.00	289.03
16	274.64	274.58
17	260.82	260.85
18	247.86	247.80
19	235.39	235.41
20	223.70	223.63
21	212.44	212.45
22	201.88	201.82
23	191.73	191.73
24	182.20	182.14
25	173.03	173.03
26	164.44	164.38
27	156.16	156.16
28	148.40	148.35
29	140.94	140.93
30	133.93	133.88
31	127.20	127.18

This says that defense weapon type 1 (anti-missile) defending target class 1 (ICBM3) has two sites. The number of dedicated defenders of the radar site and number of defenders at the sites is given as well as the base survival probability against an attack by a single attacker.

The columns give the curve fit value as well as actual expected value of surviving defenders for different attack sizes.

32	120.88	120.82
33	114.79	114.78
34	109.09	109.04
35	103.60	103.59
36	98.45	98.41
37	93.50	93.48
38	88.85	88.81
39	84.38	84.37
40	80.19	80.15
41	76.16	76.14
42	72.37	72.33
43	68.73	68.71
44	65.32	65.28
45	62.03	62.01
46	58.95	58.91
47	55.98	55.96
48	53.20	53.17
49	50.52	50.51
50	48.01	47.98
51	45.64	45.58
52	43.33	43.30
53	41.15	41.14
54	39.11	39.08
55	37.14	37.12
56	35.29	35.27
57	33.52	33.50
58	31.85	31.83
59	30.25	30.24
60	28.75	28.72
61	27.30	27.29
62	25.94	25.92
63	24.64	24.63
64	23.42	23.39
65	22.24	22.22
66	21.13	21.11
67	20.07	20.06
68	19.07	19.05
69	18.11	18.10
70	17.21	17.20
71	16.35	16.34
72	15.53	15.52
73	14.75	14.74
74	14.02	14.01
75	13.31	13.30
76	12.65	12.64
77	12.02	12.01
78	11.42	11.41
79	10.84	10.84
80	10.31	10.29
81	9.79	9.78
82	9.30	9.29
83	8.83	8.83
84	8.39	8.38
85	7.97	7.96
86	7.58	7.57
87	7.19	7.19
88	6.84	6.83
89	6.49	6.49
90	6.17	6.16
91	5.86	5.85
92	5.57	5.56
93	5.29	5.28
94	5.03	5.02
95	4.77	4.77
96	4.54	4.53
97	4.31	4.30

The next few pages give the same information for the attack on defense installations for each target class. There are six target classes. For the first three target classes (ICBMs) there is one type of missile defense only. For the last three target classes (cities) there is both missile and bomber defense.

98	4.09	4.09
99	3.89	3.88
100	3.69	3.69
101	1.91	3.50
102	1.72	3.33
103	1.55	3.16
104	1.40	3.00
105	1.26	2.85
106	1.14	2.71
107	-.00	2.58

2 1

DEF. WEAP. TYPE 1 REGION OR CITY CLASS DEFENDED 2 NO. OF BASES DEFENDED BY WEAP. TYPE 2

BASE NO.	HARDNESS(PSI)	NO. OF DEFORS. OF BASE	NO. DEFORS. AT BASE	DEFENDED BASE SURVIVAL PROB.	UNDEFENDED BASE SURVIVAL PROB.
1	50.00	54.0	264.0	.9025	.0000
2	50.00	47.0	144.0	.9025	.0000

EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE

NO. ATTACKERS	EXP. NO. SURV.	CURVE FIT VALUE
1	382.26	386.70
2	359.03	366.52
3	338.06	347.38
4	319.14	329.25
5	302.07	312.06
6	286.66	29[illegible].78
7	272.62	280.34
8	258.71	265.70
9	246.04	251.83
10	233.48	238.69
11	222.05	226.23
12	210.72	214.42
13	200.46	203.23
14	190.17	192.62
15	180.86	182.56
16	171.63	173.03
17	163.22	164.00
18	154.90	155.44
19	147.31	147.33
20	139.79	139.64
21	132.95	132.35
22	126.16	125.44
23	119.99	118.89
24	113.86	112.69
25	108.29	106.80
26	102.76	101.23
27	97.73	95.94
28	92.74	90.94
29	88.20	86.19
30	83.70	81.69
31	79.60	77.43
32	75.54	73.38
33	71.84	69.55
34	68.17	65.92
35	64.84	62.48
36	61.53	59.22
37	58.51	56.13
38	55.53	53.20
39	52.81	50.42
40	50.11	47.79
41	47.66	45.30
42	45.23	42.93
43	43.01	40.69
44	40.82	38.57

45	38.82	36.55
46	36.84	34.64
47	35.03	32.84
48	33.25	31.12
49	31.62	29.50
50	30.01	27.96
51	28.54	26.50
52	27.08	25.12
53	25.75	23.80
54	24.44	22.56
55	23.24	21.38
56	22.06	20.27
57	20.98	19.21
58	19.91	18.21
59	18.93	17.26
60	17.97	16.36
61	17.09	15.50
62	16.21	14.69
63	15.42	13.93
64	14.63	13.20
65	13.92	12.51
66	13.21	11.86
67	12.56	11.24
68	11.92	10.65
69	11.33	10.10
70	10.76	9.57
71	10.23	9.07
72	9.71	8.60
73	9.23	8.15
74	8.76	7.72
75	8.33	7.32
76	7.91	6.94
77	7.52	6.57
78	7.14	6.23
79	6.79	5.91
80	6.44	5.60
81	6.12	5.31
82	5.81	5.03
83	5.53	4.77
84	5.25	4.52
85	4.99	4.28
86	4.73	4.06
87	4.50	3.85
88	4.27	3.65
89	4.06	3.46
90	3.86	3.27
91	3.67	3.10
92	3.48	2.94
93	3.31	2.79
94	3.14	2.64
95	2.99	2.50
96	2.83	2.37
97	2.70	2.25
98	2.56	2.13
99	2.43	2.02
100	1.27	1.92
101	1.15	1.82
102	1.04	1.72
103	-.00	1.63

3 1

DEF. WEAP. TYPE 1 REGION OR CITY CLASS DEFENDED 3 NO. OF BASES DEFENDED BY WEAP. TYPE 2

BASE NO.	HARDNESS(PSI)	NO. OF DEFORS. OF BASE	NO. DEFORS. AT BASE	DEFENDED BASE SURVIVAL PROB.	UNDEFENDED BASE SURVIVAL PROB.

1	50.00	40.0	121.0	.9025	.0000
2	50.00	40.0	121.0	.9025	.0000

EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE

NO. ATTACKERS	EXP. NO. SURV.	CURVE FIT VALUE
1	230.20	229.90
2	218.41	218.41
3	207.76	207.49
4	197.11	197.12
5	187.50	187.27
6	177.89	177.91
7	169.22	169.01
8	160.55	160.57
9	152.72	152.54
10	144.89	144.91
11	137.83	137.67
12	130.77	130.79
13	124.39	124.25
14	118.02	118.04
15	112.26	112.14
16	106.51	106.53
17	101.32	101.21
18	96.13	96.15
19	91.44	91.34
20	86.75	86.78
21	82.52	82.44
22	78.30	78.32
23	74.48	74.40
24	70.66	70.68
25	67.22	67.15
26	63.77	63.79
27	60.66	60.61
28	57.55	57.58
29	54.75	54.70
30	51.94	51.96
31	49.41	49.37
32	46.88	46.90
33	44.59	44.55
34	42.31	42.33
35	40.25	40.21
36	38.18	38.20
37	36.32	36.29
38	34.46	34.48
39	32.78	32.75
40	31.10	31.12
41	29.58	29.56
42	28.07	28.08
43	26.76	26.68
44	25.33	25.35
45	24.10	24.08
46	22.86	22.88
47	21.75	21.73
48	20.63	20.65
49	19.63	19.61
50	18.62	18.63
51	17.71	17.70
52	16.81	16.82
53	15.99	15.98
54	15.17	15.18
55	14.43	14.42
56	13.69	13.70
57	13.02	13.01
58	12.35	12.36
59	11.75	11.75
60	11.15	11.16
61	10.61	10.60

62	10.06	10.07
63	9.57	9.57
64	9.08	9.09
65	8.64	8.63
66	8.20	8.20
67	7.80	7.79
68	7.40	7.40
69	7.04	7.03
70	6.68	6.68
71	6.35	6.35
72	6.02	6.03
73	5.73	5.73
74	5.44	5.44
75	5.17	5.17
76	4.91	4.91
77	4.67	4.67
78	4.43	4.43
79	4.21	4.21
80	2.21	4.00
81	2.00	3.80
82	-.00	3.61

4 1

DEF. WEAP. TYPE 1 REGION OR CITY CLASS DEFENDED 4 NO. OF BASES DEFENDED BY WEAP. TYPE 7

BASE NO.	HARDNESS(PSI)	NO. OF DEFORS. OF BASE	NO. DEFORS. AT BASE	DEFENDED BASE SURVIVAL PROB.	UNDEFENDED BASE SURVIVAL PROB.
1	50.00	21.0	84.0	.9025	.0000
2	50.00	78.0	312.0	.9025	.0000
3	50.00	12.0	48.0	.9025	.0000
4	50.00	13.0	52.0	.9025	.0000
5	50.00	80.0	358.0	.9025	.0000
6	50.00	18.0	72.0	.9025	.0000
7	50.00	8.0	32.0	.9025	.0000

EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE

NO. ATTACKERS	EXP. NO. SURV.	CURVE FIT VALUE
1	923.10	936.64
2	891.59	915.75
3	861.17	895.33
4	832.74	875.36
5	805.29	855.84
6	779.63	836.75
7	754.85	818.09
8	731.70	799.85
9	709.33	782.01
10	688.44	764.57
11	668.25	747.52
12	649.39	730.85
13	631.18	714.55
14	614.16	698.61
15	597.72	683.03
16	582.36	667.80
17	567.52	652.91
18	553.66	638.35
19	540.27	624.11
20	527.76	610.19
21	515.67	596.58
22	504.38	583.28
23	493.47	570.27
24	483.28	557.55
25	473.44	545.12
26	464.24	532.96
27	455.36	521.08
28	447.06	509.46

29	438.87	498.10
30	430.85	486.99
31	423.36	476.13
32	415.97	465.51
33	408.73	455.13
34	401.71	444.98
35	394.95	435.05
36	388.28	425.35
37	381.75	415.87
38	375.42	406.59
39	369.32	397.52
40	363.29	388.66
41	357.40	379.99
42	351.68	371.52
43	346.18	363.23
44	340.74	355.13
45	335.43	347.21
46	330.26	339.47
47	325.19	331.90
48	320.22	324.50
49	315.32	317.26
50	310.52	310.18
51	305.84	303.27
52	301.18	296.50
53	296.61	289.89
54	292.12	283.43
55	287.70	277.11
56	283.37	270.93
57	279.14	264.88
58	274.94	258.98
59	270.81	253.20
60	266.76	247.55
61	262.77	242.03
62	258.86	236.64
63	255.05	231.36
64	251.25	226.20
65	247.53	221.15
66	243.87	216.22
67	240.27	211.40
68	236.74	206.69
69	233.30	202.08
70	229.88	197.57
71	226.51	193.16
72	223.21	188.86
7	219.96	184.64
74	216.78	180.53
75	213.66	176.50
76	210.55	172.56
77	207.46	168.72
78	204.43	164.95
79	201.45	161.27
80	198.51	157.68
81	195.64	154.16
82	192.83	150.72
83	190.02	147.36
84	187.23	144.08
85	184.50	140.86
86	181.81	137.72
87	179.16	134.65
88	176.57	131.65
89	174.02	128.71
90	171.50	125.84
91	168.98	123.03
92	166.51	120.29
93	164.08	117.61
94	161.69	114.99

95	159.35	112.42
96	157.06	109.91
97	154.78	107.46
98	152.50	105.07
99	150.27	102.72
100	148.08	100.43
101	145.93	98.19
102	143.81	96.00
103	141.74	93.86
104	139.68	91.77
105	137.63	89.72
106	135.62	87.72
107	133.65	85.76
108	131.70	83.85
109	129.79	81.98
110	127.92	80.15
111	126.07	78.37
112	124.22	76.62
113	122.40	74.91
114	120.62	73.24
115	118.80	71.61
116	117.14	70.01
117	115.45	68.45
118	113.77	66.92
119	112.10	65.43
120	110.46	63.97
121	108.86	62.54
122	107.27	61.15
123	105.72	59.78
124	104.20	58.45
125	90.11	57.15
126	88.60	55.87
127	74.58	54.63
128	73.07	53.41
129	71.59	52.22
130	57.89	51.05
131	56.44	49.91
132	55.01	48.80
133	53.61	47.71
134	52.25	46.65
135	50.94	45.61
136	49.64	44.59
137	48.38	43.60
138	47.15	42.63
139	35.79	41.67
140	34.61	40.75
141	33.44	39.84
142	32.30	38.95
143	31.24	38.08
144	30.18	37.23
145	20.44	36.40
146	19.41	35.59
147	18.45	34.79
148	17.52	34.02
149	16.65	33.26
150	15.81	32.52
151	15.03	31.79
152	14.27	31.08
153	13.56	30.39
154	12.88	29.71
155	12.24	29.05
156	11.62	28.40
157	11.05	27.77
158	10.49	27.15
159	9.97	26.54
160	9.47	25.95

161	9.00	25.37
162	8.54	24.81
163	8.12	24.25
164	7.71	23.71
165	7.33	23.18
166	6.96	22.67
167	6.61	22.16
168	6.28	21.67
169	5.97	21.18
170	5.67	20.71
171	5.39	20.25
172	5.12	19.80
173	4.86	19.36
174	4.62	18.93
175	4.39	18.50
176	4.17	18.09
177	3.96	17.69
178	3.76	17.29
179	3.57	16.91
180	3.39	16.53
181	3.23	16.16
182	3.06	15.80
183	2.91	15.45
184	2.76	15.10
185	2.63	14.77
186	2.49	14.44
187	2.37	14.12
188	2.25	13.80
189	2.14	13.49
190	2.03	13.19
191	1.93	12.90
192	1.83	12.61
193	1.74	12.33
194	1.65	12.05
195	1.57	11.79
196	1.49	11.52
197	1.42	11.27
198	1.35	11.01
199	1.28	10.77
200	1.22	10.53
201	1.16	10.29
202	1.10	10.06
203	1.04	9.84
204	.99	9.62

5 1

DEF. WEAP. TYPE 1 REGION OR CITY CLASS DEFENDED 5 NO. OF BASES DEFENDED BY WEAP. TYPE 13

BASE NO.	HARDNESS(PSI)	NO. OF DEFORS. OF BASE	NO. DEFORS. AT BASE	DEFENDED BASE SURVIVAL PROB.	UNDEFENDED BASE SURVIVAL PROB.
1	50.00	16.0	48.0	.9025	.0000
2	50.00	52.0	148.0	.9025	.0000
3	50.00	15.0	44.0	.9025	.0000
4	50.00	58.0	177.0	.9025	.0000
5	50.00	20.0	60.0	.9025	.0000
6	50.00	16.0	48.0	.9025	.0000
7	50.00	10.0	30.0	.9025	.0000
8	50.00	44.0	134.0	.9025	.0000
9	50.00	36.0	109.0	.9025	.0000
10	50.00	19.0	56.0	.9025	.0000
11	50.00	24.0	74.0	.9025	.0000
12	50.00	20.0	62.0	.9025	.0000
13	50.00	15.0	45.0	.9025	.0000

EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE

NO. ATTACKERS	EXP. NO. SURV.	CURVE FIT VALUE
1	1017.74	1025.19
2	1002.17	1015.47
3	987.74	1005.84
4	973.68	996.31
5	960.62	986.87
6	947.59	977.51
7	934.91	968.24
8	923.12	959.07
9	911.36	949.98
10	899.91	940.97
11	889.27	932.05
12	878.64	923.21
13	868.04	914.46
14	857.70	905.80
15	848.10	897.21
16	838.51	888.70
17	828.94	880.28
18	819.61	871.93
19	810.94	863.67
20	802.29	855.48
21	793.65	847.37
22	785.23	839.34
23	777.41	831.38
24	769.60	823.50
25	761.80	815.70
26	754.20	807.96
27	746.99	800.31
28	739.93	792.72
29	732.88	785.21
30	725.84	777.76
31	718.99	770.39
32	712.47	763.09
33	706.10	755.85
34	699.74	748.69
35	693.39	741.59
36	687.20	734.56
37	681.16	727.60
38	675.28	720.70
39	669.43	713.87
40	663.68	707.10
41	657.94	700.40
42	652.21	693.76
43	646.62	687.18
44	641.16	680.67
45	635.71	674.22
46	630.40	667.83
47	625.12	661.50
48	619.93	655.22
49	614.75	649.01
50	609.58	642.86
51	604.54	636.77
52	599.61	630.73
53	594.69	624.75
54	589.90	618.83
55	585.14	612.96
56	580.45	607.15
57	575.77	601.40
58	571.09	595.70
59	566.42	590.05
60	561.75	584.46
61	557.20	578.92
62	552.75	573.43
63	548.31	567.99
64	543.92	562.61
65	539.60	557.28

66	535.30	551.99
67	531.01	546.76
68	526.78	541.58
69	522.56	536.44
70	518.34	531.36
71	514.12	526.32
72	509.90	521.33
73	505.80	516.39
74	501.78	511.50
75	497.77	506.65
76	493.81	501.84
77	489.92	497.09
78	486.03	492.38
79	482.16	487.71
80	478.35	483.09
81	474.54	478.51
82	470.72	473.97
83	466.91	469.48
84	463.11	465.03
85	459.41	460.62
86	455.79	456.25
87	452.17	451.93
88	448.59	447.64
89	445.07	443.40
90	441.57	439.20
91	438.08	435.03
92	434.63	430.91
93	431.19	426.82
94	427.75	422.78
95	424.32	418.77
96	420.88	414.80
97	417.54	410.87
98	414.27	406.97
99	411.00	403.12
100	407.78	399.30
101	404.60	395.51
102	401.44	391.76
103	398.29	388.05
104	395.18	384.37
105	392.08	380.73
106	388.97	377.12
107	385.87	373.54
108	382.77	370.00
109	379.76	366.49
110	376.80	363.02
111	373.86	359.58
112	370.93	356.17
113	368.02	352.79
114	365.16	349.45
115	362.30	346.14
116	359.46	342.86
117	356.65	339.61
118	353.85	336.39
119	351.05	333.20
120	348.25	330.04
121	345.45	326.91
122	342.73	323.81
123	340.07	320.74
124	337.41	317.70
125	334.77	314.69
126	332.14	311.71
127	329.55	308.75
128	326.98	305.83
129	324.41	302.93
130	321.88	300.05
131	319.35	297.21

132	316.82	294.39
133	314.29	291.60
134	311.77	288.84
135	309.31	286.10
136	306.91	283.39
137	304.51	280.70
138	302.13	278.04
139	299.76	275.41
140	297.42	272.79
141	295.10	270.21
142	292.78	267.65
143	290.50	265.11
144	288.21	262.60
145	285.93	260.11
146	283.65	257.64
147	281.37	255.20
148	279.15	252.7[illegible]
149	276.99	250.38
150	274.82	248.01
151	272.67	245.66
152	270.53	243.33
153	268.42	241.03
154	266.33	238.74
155	264.23	236.48
156	262.17	234.24
157	260.11	232.02
158	258.05	229.82
159	255.99	227.64
160	253.94	225.48
161	251.94	223.34
162	249.98	221.22
163	248.02	219.13
164	246.08	217.05
165	244.15	214.99
166	242.25	212.96
167	240.36	210.94
168	238.47	208.94
169	236.61	206.96
170	234.75	204.99
171	232.89	203.05
172	231.03	201.13
173	229.18	199.22
174	227.37	197.33
175	225.61	195.46
176	223.84	193.61
177	222.09	191.77
178	220.35	189.96
179	218.63	188.15
180	216.92	186.37
181	215.22	184.60
182	213.54	182.85
183	211.86	181.12
184	210.19	179.40
185	208.51	177.70
186	206.83	176.02
187	205.20	174.35
188	203.61	172.70
189	202.02	171.06
190	200.44	169.44
191	198.86	167.83
192	197.32	166.24
193	195.77	164.67
194	194.24	163.11
195	192.72	161.56
196	191.21	160.03
197	189.69	158.51

198	188.18	157.01
199	186.87	155.52
200	185.20	154.05
201	183.76	152.59
202	182.32	151.14
203	180.89	149.71
204	179.47	148.29
205	178.08	146.88
206	176.69	145.49
207	175.30	144.11
208	173.93	142.74
209	172.56	141.39
210	171.24	140.05
211	169.83	138.72
212	168.47	137.41
213	167.14	136.11
214	165.84	134.82
215	164.54	133.54
216	163.26	132.27
217	161.98	131.02
218	160.71	129.78
219	159.46	128.55
220	158.21	127.33
221	156.97	126.12
222	155.74	124.92
223	154.51	123.74
224	153.27	122.57
225	152.04	121.41
226	150.84	120.25
227	149.67	119.11
228	148.50	117.99
229	147.34	116.87
230	136.58	115.76
231	135.43	114.66
232	134.29	113.57
233	133.16	112.50
234	132.03	111.43
235	130.91	110.38
236	129.80	109.33
237	128.69	108.29
238	127.57	107.27
239	126.46	106.25
240	125.38	105.24
241	124.32	104.24
242	123.27	103.26
243	122.22	102.28
244	112.57	101.31
245	111.54	100.35
246	110.52	99.40
247	109.50	98.45
248	100.05	97.52
249	99.05	96.60
250	98.04	95.68
251	88.74	94.77
252	87.74	93.88
253	78.44	92.99
254	77.44	92.10
255	76.43	91.23
256	75.46	90.37
257	74.50	89.51
258	73.55	88.66
259	72.62	87.82
260	71.70	86.99
261	70.79	86.16
262	69.89	85.35
263	68.98	84.54

264	68.10	83.74
265	67.24	82.94
266	59.27	82.16
267	58.40	81.38
268	50.44	80.61
269	49.60	79.84
270	48.77	79.09
271	41.06	78.34
272	40.24	77.59
273	39.42	76.86
274	38.60	76.13
275	37.81	75.41
276	37.05	74.69
277	36.31	73.98
278	35.58	73.28
279	34.84	72.59
280	34.12	71.90
281	33.44	71.22
282	27.13	70.54
283	26.46	69.88
284	25.80	69.21
285	25.13	68.56
286	24.49	67.91
287	23.88	67.26
288	23.28	66.63
289	22.68	65.99
290	22.10	65.37
291	21.56	64.75
292	21.01	64.13
293	20.47	63.53
294	19.94	62.92
295	19.45	62.33
296	18.96	61.74
297	18.48	61.15
298	18.00	60.57
299	17.56	60.00
300	17.12	59.43
301	16.67	58.87
302	16.24	58.31
303	15.85	57.76
304	15.45	57.21
305	15.05	56.67
306	14.66	56.13
307	14.30	55.60
308	13.94	55.07
309	13.58	54.55
310	13.23	54.03
311	12.91	53.52
312	12.58	53.01
313	12.26	52.51
314	11.94	52.01
315	11.65	51.52
316	11.35	51.03
317	8.64	50.55
318	8.35	50.07
319	8.06	49.59
320	7.80	49.12
321	7,53	48.66
322	7.28	48.19
323	7.04	47.74
324	6.80	47.29
325	6.57	46.84
326	6,35	46.39
327	6.14	45.95
328	5.93	45.52
329	5.73	45.09

330	5.54	44.66
331	5.35	44.24
332	5.17	43.82
333	5.00	43.40
334	4.83	42.99
335	4.67	42.58
336	3.2[illegible]	42.18
337	3.04	41.78
338	2.89	41.38
339	2.75	40.99
340	2.61	40.60
341	2.48	40.22
342	2.35	39.84
343	2.24	39.46
344	2.12	39.08
345	2.02	38.71
346	1.92	38.35
347	1.82	37.98
348	1.73	37.62
349	1.64	37.27
350	1.56	36.91
351	1.48	36.56
352	.77	36.22

5 1

DEF. WEAP. TYPE 1 REGION OR CITY CLASS DEFENDED 6 NO. OF BASES DEFENDED BY WEAP. TYPE 3

BASE NO.	HARDNESS(PSI)	NO. OF DEFORS. OF BASE	NO. DEFORS. AT BASE	DEFENDED BASE SURVIVAL PROB.	UNDEFENDED BASE SURVIVAL PROB.
1	50.00	38.0	115.0	.9025	.0000
2	50.0	55.0	225.0	.9025	.0000
3	50.[illegible]	10.0	30.0	.9025	.0000

EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE

NO. ATTACKERS	EXP. NO. SURV.	CURVE FIT VALUE
1	348.06	353.84
2	328.26	338.39
3	310.46	323.61
4	294.27	309.47
5	279.72	295.96
6	266.58	283.03
7	254.73	270.67
8	243.51	258.85
9	232.82	247.54
10	222.70	236.73
11	213.04	226.39
12	203.91	216.50
13	195.19	207.05
14	186.95	198.00
15	179.09	189.36
16	171.65	181.08
17	164.55	173.18
18	157.84	165.61
19	151.43	158.38
20	145.37	151.46
21	139.59	144.85
22	134.13	138.52
23	128.91	132.47
24	123.97	126.68
25	119.26	121.15
26	114.81	115.86
27	110.56	110.80
28	106.54	105.96
29	102.71	101.33
30	99.08	96.91

31	95.62	92.6[illegible]
32	92.34	88.63
33	89.22	84.76
34	86.27	81.05
35	83.34	77.51
36	80.52	74.13
37	77.85	70.89
38	75.21	67.79
39	72.67	64.83
40	70.26	62.00
41	67.88	59.29
42	65.58	56.70
43	63.41	54.23
44	61.26	51.86
45	59.19	49.59
46	57.23	47.43
47	55.29	45.36
48	53.42	43.38
49	51.65	41.48
50	49.90	39.67
51	48.21	37.94
52	46.61	36.28
53	45.03	34.70
54	43.51	33.18
55	42.07	31.73
56	40.64	30.34
57	39.27	29.02
58	37.97	27.75
59	36.68	26.54
60	35.44	25.38
61	34.27	24.27
62	33.10	23.21
63	22.35	22.20
64	21.23	21.23
65	20.17	20.30
66	19.16	19.41
67	18.20	18.57
68	17.29	17.76
69	16.43	16.98
70	15.61	16.24
71	14.83	15.53
72	14.08	14.85
73	13.38	14.20
74	12.71	13.58
75	12.08	12.99
76	11.47	12.42
77	10.90	11.88
78	10.35	11.36
79	9.84	10.86
80	9.34	10.39
81	8.88	9.94
82	8.43	9.50
83	8.01	9.09
84	7.61	8.69
85	7.23	8.31
86	6.87	7.95
87	6.53	7.60
88	6.20	7.27
89	5.89	6.95
90	5.59	6.55
91	5.32	6.36
92	5.05	6.08
93	4.80	5.81
94	2.47	5.56
95	2.22	5.32
96	2.01	5.08

97	1.81	4.86
98	1.64	4.65
99	1.48	4.45
100	1.33	4.25
101	1.20	4.07
102	1.09	3.89
103	.98	3.72

1	2
2	2
3	2
4	2
5	2
6	2
1	3
2	3
3	3
4	3

DEF. WEAP. TYPE 3 REGION OR CITY CLASS DEFENDED 4 NO. OF BASES DEFENDED BY WEAP. TYPE 1

BASE NO.	HARDNESS(PSI)	NO. OF DEFRS. OF BASE	NO. DEFRS. AT BASE	DEFENDED BASE SURVIVAL PROB.	UNDEFENDED BASE SURVIVAL PROB.
1	50.00	40.0	200.0	.9025	.0000

EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE

NO. ATTACKERS	EXP. NO. SURV.	CURVE FIT VALUE
1	180.50	180.49
2	162.90	162.89
3	147.02	147.00
4	132.68	132.66
5	119.75	119.72
6	108.07	108.05
7	97.53	97.51
8	88.03	88.00
9	79.44	79.41
10	71.70	71.67
11	64.71	64.68
12	58.40	58.37
13	52.70	52.68
14	47.57	47.54
15	42.93	42.90
16	38.74	38.72
17	34.96	34.94
18	31.56	31.53
19	28.48	28.46
20	25.70	25.68
21	23.20	23.18
22	20.93	20.92
23	18.89	18.88
24	17.05	17.04
25	15.39	15.37
26	13.89	13.87
27	12.53	12.52
28	11.31	11.30
29	10.21	10.20
30	9.21	9.20

31	8.32	8.31
32	7.50	7.50
33	6.77	6.76
34	6.11	6.10
35	5.52	5.51
36	4.98	4.97
37	4.49	4.49
38	4.06	4.05
39	3.66	3.65
40	3.30	3.30
41	.00	2.98

5 3

DEF. WEAP. TYPE 3 REGION OR CITY CLASS DEFENDED 5 NO. OF BASES DEFENDED BY WEAP. TYPE 1

BASE NO.	HARDNESS(PSI)	NO. OF DEFORS. OF BASE	NO. DEFORS. AT BASE	DEFENDED BASE SURVIVAL PROB.	UNDEFENDED BASE SURVIVAL PROB.
1	50.00	50.0	300.0	.9025	.0000

EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE

NO. ATTACKERS	EXP. NO. SURV.	CURVE FIT VALUE
1	270.75	270.75
2	244.35	244.35
3	220.53	220.52
4	199.03	199.02
5	179.62	179.62
6	162.11	162.10
7	146.30	146.30
8	132.04	32.03
9	119.16	119.16
10	107.55	107.54
11	97.06	97.05
12	87.60	87.59
13	79.06	79.05
14	71.35	71.34
15	64.39	64.39
16	58.11	58.11
17	52.45	52.44
18	47.33	47.33
19	42.72	42.71
20	38.55	38.55
21	34.79	34.79
22	31.40	31.40
23	28.34	28.34
24	25.58	25.57
25	23.08	23.08
26	20.83	20.83
27	18.80	18.80
28	16.97	16.97
29	15.31	15.31
30	13.82	13.82
31	12.47	12.47
32	11.26	11.25
33	10.16	10.15
34	9.17	9.17
35	8.28	8.27
36	7.47	7.47
37	6.74	6.74
38	6.08	6.08
39	5.49	5.49
40	4.95	4.95
41	4.47	4.47
42	4.04	4.03
43	3.64	3.64
44	3.29	3.29

45	2.97	2.97
46	2.68	2.68
47	2.42	2.42
48	2.18	2.18
49	1.97	1.97
50	1.78	1.78
51	.00	1.60

6 3

DEF. WEAP. TYPE 3 REGION OR CITY CLASS DEFENDED 6 NO. OF BASES DEFENDED BY WEAP. TYPE 1

BASE NO.	HARDNESS(PSI)	NO. OF DEFORS. OF BASE	NO. DEFORS. AT BASE	DEFENDED BASE SURVIVAL PROB.	UNDEFENDED BASE SURVIVAL PROB.
1	50.00	40.0	200.0	.9025	.0000

EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE

NO. ATTACKERS	EXP. NO. SURV.	CURVE FIT VALUE
1	180.50	180.49
2	162.90	162.89
3	147.02	147.00
4	132.68	132.66
5	119.75	119.72
6	108.07	108.05
7	97.53	97.51
8	88.03	88.00
9	79.44	79.41
10	71.70	71.67
11	64.71	64.68
12	58.41	58.37
13	52.70	52.68
14	47.57	47.54
15	42.93	42.90
16	38.74	38.72
17	34.96	34.94
18	31.56	31.53
19	28.48	28.46
20	25.70	25.68
21	23.20	23.18
22	20.93	20.92
23	18.89	18.88
24	17.05	17.04
25	15.39	15.37
26	13.89	13.87
27	12.53	12.52
28	11.31	11.30
29	10.21	10.20
30	9.21	9.20
31	8.32	8.31
32	7.50	7.50
33	6.77	6.76
34	6.11	6.10
35	5.52	5.51
36	4.98	4.97
37	4.49	4.49
38	4.06	4.05
39	3.66	3.65
40	3.30	3.30
41	.00	2.98

1 4

2 4

3 4

DEF. WEAP. TYPE 4 REGION OR CITY CLASS DEFENDED 4 NO. OF BASES DEFENDED BY WEAP. TYPE 3

BASE NO.	HARDNESS(PSI)	NO. OF DEFORS. OF BASE	NO. DEFORS. AT BASE	DEFENDED BASE SURVIVAL PROB.	UNDEFENDED BASE SURVIVAL PROB.
1	50.00	35.0	200.0	.9025	.0000
2	50.00	20.0	50.0	.9025	.0000
3	50.00	20.0	100.0	.9025	.0000

EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE

NO. ATTACKERS	EXP. NO. SURV.	CURVE FIT VALUE
1	330.90	336.05
2	312.90	322.65
3	297.02	309.79
4	282.68	297.44
5	269.75	285.59
6	258.07	274.20
7	247.54	263.27
8	237.79	252.78
9	228.28	242.70
10	219.48	233.03
11	210.89	223.74
12	202.95	214.82
13	195.21	206.26
14	188.04	198.04
15	181.05	190.14
16	174.58	182.57
17	168.27	175.29
18	162.43	168.30
19	156.74	161.59
20	151.47	155.15
21	146.33	148.97
22	141.46	143.03
23	136.70	137.33
24	132.07	131.85
25	127.67	126.60
26	123.37	121.55
27	119.19	116.71
28	115.22	112.06
29	111.35	107.59
30	107.57	103.30
31	103.98	99.18
32	100.49	95.23
33	97.08	91.43
34	93.85	87.79
35	90.69	84.29
36	87.61	80.93
37	84.70	77.70
38	81.85	74.61
39	79.07	71.63
40	76.44	68.78
41	73.87	66.04
42	71.36	63.40
43	68.99	60.88
44	66.67	58.45
45	64.41	56.12
46	62.26	53.88
47	60.17	51.74
48	58.13	49.67
49	56.19	47.69
50	54.30	45.79
51	52.46	43.97
52	50.71	42.21
53	49.01	40.53
54	47.34	38.92

55	45.77	37.36
56	44.23	35.88
57	42.73	34.45
58	41.30	33.07
59	39.92	31.75
60	27.06	30.49
61	25.71	29.27
62	24.43	28.11
63	23.20	26.99
64	22.04	25.91
65	20.94	24.88
66	19.89	23.89
67	18.90	22.93
68	17.96	22.02
69	17.06	21.14
70	16.20	20.30
71	15.39	19.49
72	14.62	18.71
73	13.89	17.97
74	13.20	17.25
75	6.77	16.56
76	6.11	15.90
77	5.52	15.27
78	.00	14.66

5 4

DEF. WEAP. TYPE 4 REGION OR CITY CLASS DEFENDED 5 NO. OF BASES DEFENDED BY WEAP. TYPE 3

BASE NO.	HARDNESS(PSI)	NO. OF DEFORS. OF BASE	NO. DEFORS. AT BASE	DEFENDED BASE SURVIVAL PROB.	UNDEFENDED BASE SURVIVAL PROB.
1	50.00	20.0	100.0	.9025	.0000
2	50.00	25.0	150.0	.9025	.0000
3	50.00	15.0	50.0	.9025	.0000

EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE

NO. ATTACKERS	EXP. NO. SURV.	CURVE FIT VALUE
1	285.38	288.68
2	272.18	277.78
3	260.26	267.30
4	249.51	257.21
5	239.76	247.51
6	230.06	238.16
7	221.26	229.18
8	212.50	220.53
9	204.56	212.20
10	196.66	204.20
11	189.49	196.49
12	182.36	189.07
13	175.89	181.94
14	169.46	175.07
15	163.62	168.47
16	157.81	162.11
17	152.54	155.99
18	147.30	150.10
19	142.42	144.44
20	137.67	138.99
21	132.94	133.74
22	128.54	128.69
23	124.25	123.84
24	119.97	119.16
25	116.00	114.67
26	112.13	110.34
27	108.28	106.18
28	104.69	102.17
29	101.20	98.31

30	97.72	94.60
31	94.49	91.03
32	91.33	87.60
33	88.19	84.29
34	85.27	81.11
35	82.47	78.05
36	79.59	75.10
37	76.96	72.27
38	74.39	69.54
39	71.83	66.92
40	69.46	64.39
41	67.14	61.96
42	64.83	59.62
43	62.68	57.37
44	60.59	55.21
45	58.51	53.12
46	56.57	51.12
47	54.68	49.19
48	52.80	47.33
49	51.06	45.55
50	49.35	43.83
51	47.66	42.17
52	46.08	40.58
53	44.54	39.05
54	43.01	37.58
55	41.59	36.16
56	40.20	34.79
57	27.35	33.48
58	25.96	32.22
59	24.68	31.00
60	23.43	29.83
61	11.89	28.71
62	10.73	27.62
63	.00	26.58

6 4

DEF. WEAP. TYPE 4 REGION OR CITY CLASS DEFENDED 6 NO. OF BASES DEFENDED BY WEAP. TYPE 3

BASE NO.	HARDNESS(PSI)	NO. OF DEFORS. OF BASE	NO. DEFORS. AT BASE	DEFENDED BASE SURVIVAL PROB.	UNDEFENDED BASE SURVIVAL PROB.
1	50.00	20.0	100.0	.9025	.0000
2	50.00	15.0	50.0	.9025	.0000
3	50.00	20.0	75.0	.9025	.0000

EXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK SIZE

NO. ATTACKERS	EXP. NO. SURV.	CURVE FIT VALUE
1	215.25	216.86
2	206.45	209.01
3	198.51	201.44
4	191.20	194.15
5	184.03	187.13
6	177.43	180.36
7	170.96	173.83
8	165.01	167.54
9	159.17	161.47
10	153.79	155.63
11	148.52	150.00
12	143.65	144.57
13	138.80	139.34
14	134.04	134.29
15	129.64	129.43
16	125.26	124.75
17	120.97	120.24
18	117.00	115.88
19	113.05	111.69

20	109.18	107.65
21	105.60	103.75
22	102.03	100.00
23	98.53	96.38
24	95.30	92.89
25	92.08	89.53
26	88.93	86.29
27	86.01	83.17
28	83.10	80.16
29	80.26	77.26
30	77.62	74.46
31	75.00	71.76
32	72.43	69.17
33	70.05	66.66
34	67.69	64.25
35	65.37	61.93
36	63.22	59.68
37	61.09	57.52
38	59.00	55.44
39	57.06	53.44
40	55.13	51.50
41	53.24	49.64
42	51.50	47.84
43	49.76	46.11
44	48.05	44.44
45	46.48	42.83
46	44.91	41.28
47	43.37	39.79
48	41.94	38.35
49	40.53	36.96
50	39.14	35.62
51	26.29	34.33
52	25.00	33.09
53	23.72	31.89
54	22.57	30.74
55	11.83	29.63
56	10.68	28.56
57	9.64	27.52
58	.00	26.53

NUMBER OF K TH TYPE SIDE 2 DEFORS. (ACCROSS) OFI TH TYPE TARGET (DOWN)

	1	2	3	4
1	624.0	.0	.0	.0
2	408.0	.0	.0	.0
3	242.0	.0	.0	.0
4	958.0	.0	200.0	350.0
5	1035.0	.0	300.0	300.0
6	370.0	.0	200.0	225.0

These give the total inventory of each defender type for each target class.

CURVE FIT VALUES FOR Q(I,K), K(ACCROSS) , I(DOWN)

	1	2	3	4
1	.9500	1.0000	1.0000	1.0000
2	.9478	1.0000	1.0000	1.0000
3	.9500	1.0000	1.0000	1.0000
4	.9777	1.0000	.9025	.9801
5	.9905	1.0000	.9025	.9623
6	.9563	1.0000	.9025	.9638

This case uses the attack on defense option and the objective is to maximize damage to side two cities. All allocations are thus countervalue. The actual allocations show that the missiles are allocated to the East and West Coast and the bombers are allocated to the Midwest. The corresponding defenses are also attacked and almost entirely destroyed. There are small miscellaneous allocations again because the marginal return of further missile allocations to the East and West is very small, and there are not sufficient missiles left to overcome the missile defense of the Midwest. The damage is .730 to side one and .703 to side two.

**********STRATEGIC WEAPONS EXCHANGE MODELS (SWEM) **********

ALLOCATION OPTIMIZATION MODEL
STRATEGIC ANALYSIS OF EXCHANGE

***** DAMAGE TO SIDE ONE ***** .730

***** DAMAGE TO SIDE TWO ***** .703

NEW SIDE ONE ARSENAL
SIDE ONE COUNTERFORCE STRIKE CHARACTERISTICS

INTERPRETATION OF EACH SET OF ENTRIES

MISSILES OF TYPE (COLUMN) ALLOCATED AGAINST TARGET (ROW)
MISSILE OF TYPE (COLUMN) ARRIVING OVER TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) ARRIVING OVER TARGET
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON EACH MISSILE (ROW)
SURVIVAL PROB. OF EACH MISSILE TYPE (ROW) FROM ATTACK BY MISSILE (COLUMN)

	ICBMH	ICBME	ICBMG	ICBMI	ICBMJ	ICBMK	
	1.0	.9	.8	.5	.3	.3	
	.8	.8	.6	.4	.2	.2	
ICBM3	.8	.8	.6	1.2	1.5	1.3	
	.0	.0	.0	.0	.0	.0	
	.000	.000	.000	.000	.000	.000	Essentially no counterforce attack.
	1.000	1.000	1.000	1.000	1.000	1.000	
	1.0	.9	.8	.5	.3	.3	
	.8	.8	.6	.4	.2	.2	
ICBM2	.8	.8	.6	1.2	1.5	1.3	
	.0	.0	.0	.0	.0	.0	
	.000	.000	.000	.000	.000	.000	
	1.000	1.000	1.000	1.000	1.000	1.000	
	1.0	.9	.8	.5	.3	.3	
	.8	.8	.6	.4	.2	.2	
ICBM1	.8	.8	.6	1.2	1.5	1.3	
	.0	.0	.0	.0	.0	.0	
	.000	.000	.000	.000	.000	.000	
	1.000	1.000	1.000	1.000	1.000	1.000	

SIDE ONE COUNTERVALUE STRIKE CHARACTERISTICS

INTERPRETATION OF EACH SET OF ENTRIES

WEAPONS OF TYPE (COLUMN) ALLOCATED AGAINST CITY CLASS (ROW)
WEAPONS OF TYPE (COLUMN) ARRIVING OVER CITY CLASS (ROW)
WEAPONS OF TYPE (COLUMN) IMPACTING ON CITY CLASS
NO. OF 1 MT. EQS. FROM WEAPON TYPE (COLUMN) IMPACTING ON CITY CLASS (ROW)

CITY CLASS	ICBMH	ICBME	ICBMG	ICBMI	ICBMJ	ICBMK	ICBMA	ICBMB	ICBMC	ICBMD	ICBMF	SLBMA
	73.3	9.1	20.0	52.5	70.0	58.2	.6	.4	.2	.1	8.6	9.8
1	58.7	7.2	15.0	39.4	56.0	46.6	.5	.3	.1	.1	6.0	7.4
	55.9	6.9	14.3	37.6	53.3	44.4	.5	.3	.1	.1	5.7	7.0
	94.8	10.2	64.0	225.3	378.7	315.3	1.0	.5	.1	.1	8.3	10.2
	6.4	5.2	3.0	2.1	1.4	1.1	1.7	.6	.2	.1	2.4	.6
2	5.1	4.2	2.2	1.6	1.1	.9	1.2	.4	.1	.1	1.7	.4
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	82.2	9.4	14.6	18.8	15.7	14.8	27.0	13.8	34.6	34.7	58.4	19.5
3	65.7	7.5	11.0	14.1	12.6	11.8	20.3	9.6	27.7	26.0	40.9	14.7
	61.6	7.1	10.3	13.2	11.8	11.1	19.0	9.0	26.0	24.4	38.3	13.7
	93.5	10.5	46.0	79.4	83.8	78.7	42.5	18.1	29.6	15.4	55.5	19.9

CITY CLASS	SLBMB	SLBMC	BOMBA	
	235.8	173.2	.3	
1	176.8	129.9	.2	East
	168.6	123.8	.0	
	255.7	166.1	.0	
	.6	1.9	174.4	
2	.4	1.4	130.8	Midwest
	.0	.0	122.0	
	.0	.0	244.0	
	13.5	24.5	.3	
3	10.1	18.4	.2	West
	9.5	17.2	.0	
	14.4	23.1	.0	

SIDE ONE COUNTER DEFENSE STRIKE CHARACTERISTICS

SIDE ONE (ALLOCATIONS) ON DEFENSES OF RESOURCE TYPE (ROWS) DEFENDED BY DFDR. TYPE (COLS.)
(ARRIVALS)
SIDE TWO (ORIG. NO.) OF DEFDRS. OF RESOURCE TYPE (ROWS) ATTACKED BY OFFS.
SIDE TWO (SURV. NO.) OF DEFDRS. OF RESOURCE TYPE (ROWS) ATTACKED BY OFFS.

	1	2	3	4
1	.9	.9	.9	.9
	.7	.7	.7	.7
	624.0	.0	.0	.0
	601.7	.0	.0	.0
2	.9	.9	.9	.9
	.7	.7	.7	.7
	408.0	.0	.0	.0
	392.8	.0	.0	.0
3	.9	.9	.9	.9
	.7	.7	.7	.7
	242.0	.0	1.0	.0
	233.4	.0	.0	.0
4	243.2	4.4	5.0	5.6
	194.6	3.5	3.7	4.2
	958.0	.0	200.0	350.0
	11.9	.0	136.1	294.9
5	4.7	4.4	69.0	132.2
	3.8	3.5	51.7	99.2
	1035.0	.0	300.0	300.0
	998.4	.0	1.5	6.6
6	105.5	4.4	4.7	4.7
	84.4	3.6	3.6	3.6
	370.0	.0	200.0	225.0
	8.5	.0	139.9	197.4

This matrix gives the counterdefense strike characteristics. The rows are the target classes from 1-6. The columns are the defense type's So this matrix shows a heavy attack on defense type one (anti-missile) for target class 4 and 6 (East, Midwest) The numbers for the attack on defender type one in target class 4 are that 243 missiles were allocated to the attack, 195 arrived. There were originally 958 defenders and 11.9 survived the attack.

SIDE TWO SECOND STRIKE CHARACTERISTICS

INTERPRETATION OF EACH SET OF ENTRIES

NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) BEFORE COUNTERFORCE STRIKE
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) SURVIVING COUNTERFORCE STRIKE
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) ARRIVING OVER CITIES
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) IMPACTING ON SIDE ONE CITIES
NO. OF 1 MT. EQS. FROM EACH WEAPON TYPE (COLUMN) IMPACTING ON CITIES

	ICBM3	ICBM2	ICBM1	SLBM1	SLBM2	BOMB1	BOMB2	BOMB3	BOMB4	BOMB5
	600.0	400.0	30.0	150.0	375.0	40.0	125.0	40.0	40.0	50.0
1.	600.0	400.0	30.0	150.0	375.0	40.0	125.0	40.0	40.0	50.0
	468.0	320.0	22.2	93.0	225.0	28.8	90.0	28.8	28.8	36.0
	143.8	98.4	6.8	28.6	69.2	.0	.1	.0	.0	.0
	121.7	98.4	16.7	29.3	50.9	.9	.2	.2	.2	.0

This case uses the attack on defenses option and the objective is to minimize damage to side one. The attack is entirely counter-force and all ICBMs are destroyed. The defenses of the ICBMs are also attacked and almost entirely destroyed. The minimum damage is .053 which is to be contrasted with .485 damage with no attack on defenses.

**********STRATEGIC WEAPONS EXCHANGE MODELS (SWEM) **********

ALLOCATION OPTIMIZATION MODEL
STRATEGIC ANALYSIS OF EXCHANGE

***** DAMAGE TO SIDE ONE ***** .053

***** DAMAGE TO SIDE TWO ***** .036

NEW SIDE ONE ARSENAL
SIDE ONE COUNTERFORCE STRIKE CHARACTERISTICS

INTERPRETATION OF EACH SET OF ENTRIES

MISSILES OF TYPE (COLUMN) ALLOCATED AGAINST TARGET (ROW)
MISSILE OF TYPE (COLUMN) ARRIVING OVER TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) ARRIVING OVER TARGET
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON EACH MISSILE (ROW)
SURVIVAL PROB. OF EACH MISSILE TYPE (ROW) FROM ATTACK BY MISSILE (COLUMN)

	ICBMH	ICBMF	ICBMG	ICBMI	ICBMJ	ICBMK
	.0	19.1	.0	56.9	74.7	24.1
	.0	15.3	.0	42.7	59.7	19.3
ICBM3	.0	15.3	.0	128.0	358.4	115.8
	.0	14.5	.0	120.8	338.5	109.3
	.000	.224	.000	.221	.564	.182
	1.000	.967	1.000	.445	.090	.459
	131.6	.0	39.9	.0	11.9	42.7
	105.3	.0	29.9	.0	9.5	34.2
ICBM2	105.3	.0	29.9	.0	56.9	205.1
	100.3	.0	28.5	.0	54.2	195.5
	.251	.000	.071	.000	.136	.489
	.318	1.000	.723	1.000	.960	.124
	47.7	.1	.0	.0	.4	7.5
	38.1	.0	.0	.0	.3	6.0
ICBM1	38.1	.0	.0	.0	1.7	36.0
	14.4	.0	.0	.0	.6	13.6
	.481	.001	.000	.000	.021	.465
	.111	.999	1.000	.999	.912	.143

SIDE ONE COUNTERVALUE STRIKE CHARACTERISTICS

INTERPRETATION OF EACH SET OF ENTRIES

WEAPONS OF TYPE (COLUMN) ALLOCATED AGAINST CITY CLASS (ROW)
WEAPONS OF TYPE (COLUMN) ARRIVING OVER CITY CLASS (ROW)
WEAPONS OFTYPE (COLUMN) IMPACTING ON CITY CLASS
NO. OF 1 MT. EQS. FROM WEAPON TYPE (COLUMN) IMPACTING ON CITY CLASS (ROW)

CITY CLASS	ICBMH	ICBMF	ICBMG	ICBMI	ICBMJ	ICBMK	ICBMA	ICBMB	ICBMC	ICBMD	ICBMF	SLBMA
	6.2	2.5	.0	5.6	.1	.1	7.5	3.8	8.7	8.7	17.5	7.5
1	5.0	2.0	.0	4.2	.1	.1	5.6	2.6	7.0	6.6	12.2	5.6
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	6.2	2.5	.0	6.1	.1	.1	7.5	3.8	8.8	8.8	17.5	7.5
2	5.0	2.0	.0	4.6	.1	.1	5.6	2.6	7.0	6.6	12.3	5.6
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	6.2	2.5	.0	6.1	.1	.1	7.5	3.7	8.7	8.7	17.5	7.5
3	5.0	2.0	.0	4.6	.1	.1	5.6	2.6	7.0	6.6	12.3	5.6
	.1	.0	.0	.1	.0	.0	.1	.1	.1	.1	.3	.1
	.2	.1	.0	.6	.0	.0	.3	.1	.2	.1	.4	.2

	SLBMB	SLBMC	BOMBA
	62.5	50.0	43.7
1	46.9	37.5	32.8
	.0	.0	.0
	.0	.0	.0
	62.5	50.0	43.8
2	46.9	37.5	32.8
	.0	.0	.0
	.0	.0	.0
	62.5	50.0	43.8
3	46.9	37.5	32.8
	1.0	.8	.0
	1.5	1.1	.0

SIDE CNE COUNTER DEFENSE STRIKE CHARACTERISTICS
SIDE CNE (ALLOCATIONS) ON DEFENSES OF RESOURCE TYPE (ROWS) DEFENDED BY DFDR. TYPE (COLS.)
(ARRIVALS)
SIDE TWO (ORIG. NO.) OF DEFDRS. OF RESOURCE TYPE (ROWS) ATTACKED BY OFFS.
SIDE TWC (SURV. NO.) OF DEFDRS. OF RESOURCE TYPE (ROWS) ATTACKED BY OFFS.

	1	2	3	4
1	125.8	10.9	12.8	12.8
	100.6	8.7	9.6	9.6
	624.0	.0	.0	.0
	3.6	.0	.0	.0
2	108.2	12.0	12.8	12.8
	86.6	9.6	9.6	9.6
	468.0	.0	.0	.0
	3.9	.0	.0	.0
3	61.1	12.1	12.9	12.9
	48.9	9.7	9.7	9.7
	242.0	.0	1.0	.0
	19.7	.0	.0	.0
4	12.2	12.2	13.0	13.0
	9.8	9.8	9.8	9.8
	958.0	.0	200.0	350.0
	768.6	.0	73.4	235.3
5	12.2	12.2	13.0	13.0
	9.8	9.8	9.8	9.8
	1035.0	.0	300.0	300.0
	943.1	.0	110.2	206.1
6	12.2	12.2	13.0	13.0
	9.8	9.8	9.8	9.8
	370.0	.0	200.0	225.0
	239.2	.0	73.4	157.0

This matrix gives the counterdefense strike characteristics. The rows are the target classes from 1-6. The columns are the defense types. So this matrix shows a heavy attack on defense type 1 (anti-missile) for target class 1, 2, and 3 (ICBM). The numbers for the attack on defender type 1 in target class 1 are that 125.8 missiles were allocated to the attack, 100.6 arrived. There were originally 624 defenders and 3.6 survive the attack.

SIDE TWO SECOND STRIKE CHARACTERISTICS

INTERPRETATION OF EACH SET OF ENTRIES

NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) BEFORE COUNTERFORCE STRIKE
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) SURVIVING COUNTERFORCE STRIKE
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) ARRIVING OVER CITIES
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) IMPACTING ON SIDE ONE CITIES
NO. OF 1 MT. EQS. FROM EACH WEAPON TYPE (COLUMN) IMPACTING ON CITIES

	ICBM3	ICBM2	ICBM1	SLBM1	SLBM2	BOMB1	BOMB2	BOMB3	BOMB4	BOMB5
	600.0	400.0	30.0	150.0	375.0	40.0	125.0	40.0	40.0	50.0
1	10.6	6.4	.4	150.0	375.0	40.0	125.0	40.0	40.0	50.0
	8.3	5.1	.3	93.0	225.0	28.8	90.0	28.8	28.8	36.0
	.1	.1	.0	1.7	4.1	.0	.1	.0	.0	.0
	.1	.1	.0	1.7	3.0	.9	.2	.2	.2	.0

This case uses the option of attack on defenses and minimizes the differences in damage between the two nations (attack is both counterforce and countervalue). To obtain the minimum damage difference several values of K were run between .1 and 10. This case was for a value of K = .2 and was the minimum difference for the runs performed.

The results show a counterforce attack against all three ICBMs which destroys them, and an attack against the defenses of the ICBM which are also almost entirely destroyed. The allocation of the countervalue missiles is to the Western cities (because of higher defense) and the bombers are allocated to the East. There are miscellaneous missile allocations because no more damage can be done to the West by further allocation and there are essentially not enough missiles left to overcome the strong missile defense of the East and Midwest. The damages are .067 to side one and .315 to side two. This is to be contrasted to the case of .485 to side one and .082 to side two with no attack on defenses. By attacking the defenses we have substantially decreased damage to side one and substantially increased damage to side two.

**********STRATEGIC WEAPONS EXCHANGE MODELS (SWEM) **********

ALLOCATION OPTIMIZATION MODEL
STRATEGIC ANALYSIS OF EXCHANGE

***** DAMAGE TO SIDE ONE ***** .067

***** DAMAGE TO SIDE TWO ***** .315

NEW SIDE ONE ARSENAL
SIDE ONE COUNTERFORCE STRIKE CHARACTERISTICS

INTERPRETATION OF EACH SET OF ENTRIES

MISSILES OF TYPE (COLUMN) ALLOCATED AGAINST TARGET (ROW)
MISSILE OF TYPE (COLUMN) ARRIVING OVER TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) ARRIVING OVER TARGET
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON EACH MISSILE (ROW)
SURVIVAL PROB. OF EACH MISSILE TYPE (ROW) FROM ATTACK BY MISSILE (COLUMN)

	ICBMH	ICBME	ICBMG	ICBMI	ICBMJ	ICBMK
	133.8	.0	40.0	74.6	30.2	41.7
	107.0	.0	30.0	56.0	24.2	33.3
ICBM3	107.0	.0	30.0	167.9	145.1	199.9
	70.6	.0	19.8	110.7	95.7	131.9
	.118	.000	.033	.184	.159	.220
	.585	1.000	.859	.477	.506	.391
	76.1	.0	.0	.0	57.7	25.3
	60.9	.0	.0	.0	46.2	20.2
ICBM2	60.9	.0	.0	.0	277.0	121.3
	38.4	.0	.0	.0	174.9	76.6
	.096	.000	.000	.000	.437	.191
	.645	1.000	1.000	1.000	.154	.441
	69.4	.0	.0	.0	.0	.7
	55.5	.0	.0	.0	.0	.5
ICBM1	55.5	.0	.0	.0	.1	3.3
	20.9	.0	.0	.0	.0	1.2
	.697	.000	.000	.000	.001	.041
	.042	1.000	1.000	1.000	.995	.839

SIDE ONE COUNTERVALUE STRIKE CHARACTERISTICS

INTERPRETATION OF EACH SET OF ENTRIES

WEAPONS OF TYPE (COLUMN) ALLOCATED AGAINST CITY CLASS (ROW)
WEAPONS OF TYPE (COLUMN) ARRIVING OVER CITY CLASS (ROW)
WEAPONS OFTYPE (COLUMN) IMPACTING ON CITY CLASS
NO. OF 1 MT. EQS. FROM WEAPON TYPE (COLUMN) IMPACTING ON CITY CLASS (ROW)

CITY CLASS	ICBMH	ICBME	ICBMG	ICBMI	ICBMJ	ICBMK	ICBMA	ICBMB	ICBMC	ICBMD	ICBMF	SLBMA
	1.0	8.5	.0	.1	.0	.3	5.0	3.0	1.8	.0	6.7	4.8
1	.8	6.8	.0	.1	.0	.2	3.7	2.1	1.4	.0	4.7	3.6
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	8.4	6.7	.0	.1	.0	.8	4.9	3.1	1.8	.0	7.0	4.8
2	6.7	5.4	.0	.1	.0	.7	3.7	2.1	1.4	.0	4.9	3.6
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	13.1	5.1	.0	.1	.0	6.3	15.1	5.8	29.6	34.9	49.4	15.6
3	10.5	4.1	.0	.1	.0	5.0	11.4	4.1	23.7	26.2	34.5	11.7
	8.2	3.2	.0	.1	.0	3.9	8.8	3.2	18.4	20.4	26.9	9.1
	12.4	4.7	.0	.4	.0	27.7	19.8	6.4	21.0	12.8	39.0	13.2

	SLBMB	SLBMC	BOMBA	
	11.3	21.0	172.3	
1	8.3	15.7	129.2	East (city class 1)
	.0	.0	112.0	
	.0	.0	223.9	
	10.9	17.1	1.4	
2	8.2	12.9	1.0	
	.0	.0	.0	Midwest (city class 2)
	.0	.0	.0	
	217.1	143.3	.0	
3	162.8	107.5	.0	West (city class 3)
	126.8	83.7	.0	
	192.3	112.3	.0	

SIDE ONE COUNTER DEFENSE STRIKE CHARACTERISTICS

SIDE ONE (ALLOCATIONS) ON DEFENSES OF RESOURCE TYPE (ROWS) DEFENDED BY OFOR. TYPE (COLS.)
(ARRIVALS)
SIDE TWO (ORIG. NO.) OF DEFORS. OF RESOURCE TYPE (ROWS) ATTACKED BY OFFS.
SIDE TWO (SURV. NO.) OF DEFORS. OF RESOURCE TYPE (ROWS) ATTACKED BY OFFS.

	1	2	3	4	
	62.7	4.1	4.2	4.2	
1	50.1	3.2	3.2	3.2	
	624.0	.0	.0	.0	
	47.7	.0	.0	.0	
	63.2	4.1	4.4	4.4	
2	50.8	3.3	3.3	3.3	
	408.0	.0	.0	.0	
	26.7	.0	.0	.0	
	55.3	4.1	4.4	4.4	
3	44.2	3.3	3.3	3.3	
	242.0	.0	.0	.0	
	25.0	.0	.0	.0	
	1.7	1.4	43.1	122.5	
4	1.3	1.1	32.4	91.9	
	958.0	.0	200.0	350.0	(East)
	929.4	.0	7.2	8.3	
	.5	.5	.5	.5	
5	.4	.4	.4	.4	(Midwest)
	1035.0	.0	300.0	300.0	
	1031.4	.0	289.0	295.6	
	58.4	3.3	3.6	3.6	
6	46.7	2.7	2.7	2.7	(West)
	370.0	.0	200.0	225.0	
	45.9	.0	152.0	203.9	

Attack on defenses is to destroy missile defense of ICBM, missile defense defense of West Coast, and bomber defense of East Coast.

SIDE TWO SECOND STRIKE CHARACTERISTICS

INTERPRETATION OF EACH SET OF ENTRIES

NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) BEFORE COUNTERFORCE STRIKE
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) SURVIVING COUNTERFORCE STRIKE
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) ARRIVING OVER CITIES
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) IMPACTING ON SIDE ONE CITIES
NO. OF 1 MT. EQS. FROM EACH WEAPON TYPE (COLUMN) IMPACTING ON CITIES

	ICBM3	ICBM2	ICBM1	SLBM1	SLBM2	BOMB1	BOMB2	BOMB3	BOMB4	BOMB5
	600.0	400.0	30.0	150.0	375.0	40.0	125.0	40.0	40.0	50.0
1	28.4	17.6	1.0	150.0	375.0	40.0	125.0	40.0	40.0	50.0
	22.1	14.0	.8	93.0	225.0	28.8	90.0	28.8	28.8	36.0
	.5	.3	.0	2.2	5.3	.0	.1	.0	.0	.0
	.4	.3	.0	2.2	3.9	.9	.2	.2	.2	.0

This case uses the no attack on defense option and the objective is to maximize the damage to side two. The allocation is all countervalue and the missiles are allocated to the East Coast while the bombers are allocated to the West Coast. The damage is .730 to side one and .320 to side two.

**********STRATEGIC WEAPONS EXCHANGE MODELS (SWEM) **********

ALLOCATION OPTIMIZATION MODEL
STRATEGIC ANALYSIS OF EXCHANGE

***** DAMAGE TO SIDE ONE ***** .730

***** DAMAGE TO SIDE TWO ***** .320

NEW SIDE ONE ARSENAL
SIDE ONE COUNTERFORCE STRIKE CHARACTERISTICS

INTERPRETATION OF EACH SET OF ENTRIES

MISSILES OF TYPE (COLUMN) ALLOCATED AGAINST TARGET (ROW)
MISSILE OF TYPE (COLUMN) ARRIVING OVER TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) ARRIVING OVER TARGET
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON EACH MISSILE (ROW)
SURVIVAL PROB. OF EACH MISSILE TYPE (ROW) FROM ATTACK BY MISSILE (COLUMN)

	ICBMH	ICBME	ICBMG	ICBMI	ICBMJ	ICBMK
	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0
ICBM3	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0
	.000	.000	.000	.000	.000	.000
	1.000	1.000	1.000	1.000	1.000	1.000
	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0
ICBM2	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0
	.000	.000	.000	.000	.000	.000
	1.000	1.000	1.000	1.000	1.000	1.000
	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0
ICBM1	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0
	.000	.000	.000	.000	.000	.000
	1.000	1.000	1.000	1.000	1.000	1.000

SIDE ONE COUNTERVALUE STRIKE CHARACTERISTICS

INTERPRETATION OF EACH SET OF ENTRIES

WEAPONS OF TYPE (COLUMN) ALLOCATED AGAINST CITY CLASS (ROW)
WEAPONS OF TYPE (COLUMN) ARRIVING OVER CITY CLASS (ROW)
WEAPONS OFTYPE (COLUMN) IMPACTING ON CITY CLASS
NO. OF 1 MT. EQS. FROM WEAPON TYPE (COLUMN) IMPACTING ON CITY CLASS (ROW)

CITY CLASS	ICBMH	ICBME	ICBMG	ICBMI	ICBMJ	ICBMK	ICBMA	ICBMB	ICBMC	ICBMD	ICBMF	SLBMA
1	750.0	30.0	40.0	75.0	88.0	75.0	30.0	15.0	35.0	35.0	70.0	30.0
	600.0	24.0	30.0	56.3	70.4	60.0	22.5	10.5	28.0	25.3	49.0	22.5
	125.1	5.0	6.3	11.7	14.7	12.5	4.7	2.2	5.8	5.5	10.2	4.7
	189.8	7.4	28.0	70.4	104.2	88.8	10.5	4.4	6.7	3.4	14.8	6.8
2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

CITY CLASS	SLBMB	SLBMC	BOMBA
1	250.0	200.0	.0
	187.5	150.0	.0
	39.1	31.3	.0
	59.3	42.0	.0
2	.0	.0	.0
	.0	.0	.0
	.0	.0	.0
	.0	.0	.0
3	.0	.0	175.0
	.0	.0	131.3
	.0	.0	2.8
	.0	.0	5.5

SIDE TWO SECOND STRIKE CHARACTERISTICS

INTERPRETATION OF EACH SET OF ENTRIES

NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) BEFORE COUNTERFORCE STRIKE
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) SURVIVING COUNTERFORCE STRIKE
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) ARRIVING OVER CITIES
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) IMPACTING ON SIDE ONE CITIES
NO. OF 1 MT. EQS. FROM EACH WEAPON TYPE (COLUMN) IMPACTING ON CITIES

	ICBM3	ICBM2	ICBM1	SLBM1	SLBM2	BOMB1	BOMB2	BOMB3	BOMB4	BOMB5
	600.0	400.0	30.0	150.0	375.0	40.0	125.0	40.0	40.0	50.0
	600.0	400.0	30.0	150.0	375.0	40.0	125.0	40.0	40.0	50.0
1	468.0	320.0	22.2	93.0	225.0	28.8	90.0	28.8	28.8	36.0
	143.8	98.4	6.8	28.6	69.2	.0	.1	.0	.0	.0
	121.7	98.4	16.7	29.3	50.9	.3	.2	.2	.2	.0

This case uses the option of not allowing attack on defenses. The objective is to minimize the damage to side one (first strike) so the attack will be counterforce. The results show that the attack is against ICBM2 and ICBM1 which are both completely destroyed, while ICBM3 is not attacked. All side one missiles which have counterforce capability are used in the attack. The minimum damage is .485.

**********STRATEGIC WEAPONS EXCHANGE MODELS (SWEM) **********

ALLOCATION OPTIMIZATION MODEL
STRATEGIC ANALYSIS OF EXCHANGE

***** DAMAGE TO SIDE ONE ***** .485 — This is the minimum damage for side one which can be obtained by allocating all counterforce weapons to a counterforce attack.

***** DAMAGE TO SIDE TWO ***** .000 — Damage is zero because no value was input for damage to side two.

~~NEW SIDE ONE ADDENM~~

SIDE ONE COUNTERFORCE STRIKE CHARACTERISTICS

INTERPRETATION OF EACH SET OF ENTRIES

MISSILES OF TYPE (COLUMN) ALLOCATED AGAINST TARGET (ROW)
MISSILE OF TYPE (COLUMN) ARRIVING OVER TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) ARRIVING OVER TARGET
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON EACH MISSILE (ROW)
SURVIVAL PROB. OF EACH MISSILE TYPE (ROW) FROM ATTACK BY MISSILE (COLUMN)

	ICBMH	ICBME	ICBMG	ICBMI	ICBMJ	ICBMK
	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0
ICBM3	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0
	.000	.000	.000	.000	.000	.000
	1.000	1.000	1.000	1.000	1.000	1.000
	543.5	10.6	19.9	65.3	84.5	71.5
	434.8	8.5	14.9	49.0	67.6	57.2
ICBM2	434.8	8.5	14.9	147.0	405.5	343.2
	105.9	2.1	3.6	35.8	98.8	83.6
	.265	.005	.009	.090	.247	.209
	.299	.993	.959	.698	.348	.409
	206.5	19.4	20.1	9.7	3.5	3.5
	165.2	15.5	15.1	7.3	2.8	2.8
ICBM1	165.2	15.5	15.1	21.8	16.9	16.8
	13.1	1.2	1.2	1.7	1.3	1.3
	.435	.041	.040	.057	.044	.044
	.137	.945	.833	.794	.827	.827

This shows results of counterforce attack.

RAC

SIDE ONE COUNTERVALUE STRIKE CHARACTERISTICS

INTERPRETATION OF EACH SET OF ENTRIES

WEAPONS OF TYPE (COLUMN) ALLOCATED AGAINST CITY CLASS (ROW)
WEAPONS OF TYPE (COLUMN) ARRIVING OVER CITY CLASS (ROW)
WEAPONS OFTYPE (COLUMN) IMPACTING ON CITY CLASS
NO. OF 1 MT. EQS. FROM WEAPON TYPE (COLUMN) IMPACTING ON CITY CLASS (ROW)

CITY CLASS	ICBMH	ICBME	ICBMG	ICBMI	ICBMJ	ICBMK	ICBMA	ICBMB	ICBMC	ICBMD	ICBMF	SLBMA
	.0	.0	.0	.0	.0	.0	7.5	3.7	8.7	8.7	17.5	7.5
1	.0	.0	.0	.0	.0	.0	5.6	2.6	7.0	6.6	12.2	5.6
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	7.5	3.7	8.7	8.8	17.5	7.5
2	.0	.0	.0	.0	.0	.0	5.6	2.6	7.0	6.6	12.2	5.6
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	7.5	3.7	8.7	8.8	17.5	7.5
3	.0	.0	.0	.0	.0	.0	5.6	2.6	7.0	6.6	12.2	5.6
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

CITY CLASS	SLBMB	SLBMC	BOMBA
	62.5	50.0	43.7
1	46.9	37.5	32.8
	.0	.0	.0
	.0	.0	.0
	62.5	50.0	43.8
2	46.9	37.5	32.8
	.0	.0	.0
	.0	.0	.0
	62.5	50.0	43.7
3	46.9	37.5	32.8
	.1	.1	.0
	.1	.1	.0

Countervalue only weapons are not optimized because no value was attached to damage to side two.

SIDE TWO SECOND STRIKE CHARACTERISTICS

INTERPRETATION OF EACH SET OF ENTRIES

NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) BEFORE COUNTERFORCE STRIKE
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) SURVIVING COUNTERFORCE STRIKE
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) ARRIVING OVER CITIES
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) IMPACTING ON SIDE ONE CITIES
NO. OF 1 MT. EQS. FROM EACH WEAPON TYPE (COLUMN) IMPACTING ON CITIES

	ICBM3	ICBM2	ICBM1	SLBM1	SLBM2	BOMB1	BOMB2	BOMB3	BOMB4	BOMB5
	600.0	400.0	30.0	150.0	375.0	40.0	125.0	40.0	40.0	50.0
1	600.0	11.3	1.8	150.0	375.0	40.0	125.0	40.0	40.0	50.0
	468.0	9.0	1.3	93.0	225.0	28.8	90.0	28.8	28.8	36.0
	88.0	1.7	.2	17.5	42.3	.0	.1	.0	.0	.0
	74.5	1.7	.6	17.9	31.1	.3	.2	.2	.2	.0

This case uses the no attack on defense option and minimizes the difference in damage between the two nations. Several cases were run for values of K between .1 and 10. This case (K = .2) gave the minimum difference. The counterforce attack is allocated to ICBM2 and ICBM1 which are almost completely destroyed, and the countervalue attack is to the West Coast. The damages are .485 to side one and .082 to side two.

**********STRATEGIC WEAPONS EXCHANGE MODELS (SWEM) **********

ALLOCATION OPTIMIZATION MODEL
STRATEGIC ANALYSIS OF EXCHANGE

***** DAMAGE TO SIDE ONE ***** .485

***** DAMAGE TO SIDE TWO ***** .082

NEW SIDE ONE ARSENAL
SIDE ONE COUNTERFORCE STRIKE CHARACTERISTICS

INTERPRETATION OF EACH SET OF ENTRIES

MISSILES OF TYPE (COLUMN) ALLOCATED AGAINST TARGET (ROW)
MISSILE OF TYPE (COLUMN) ARRIVING OVER TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) ARRIVING OVER TARGET
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON TARGET (ROW)
WARHEADS OF MISSILE TYPE (COLUMN) IMPACTING ON EACH MISSILE (ROW)
SURVIVAL PROB. OF EACH MISSILE TYPE (ROW) FROM ATTACK BY MISSILE (COLUMN)

	ICBMH	ICBME	ICBMG	ICBMI	ICBMJ	ICBMK
	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0
ICBM3	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0
	.000	.000	.000	.000	.000	.000
	1.000	1.000	1.000	1.000	1.000	1.000
	542.3	11.0	20.5	65.6	84.5	71.5
	433.8	8.8	15.4	49.2	67.6	57.2
ICBM2	433.8	8.8	15.4	147.7	405.4	343.1
	105.7	2.1	3.8	36.0	98.8	83.6
	.264	.005	.009	.090	.247	.209
	.300	.993	.958	.697	.348	.409
	207.7	19.3	19.5	9.4	3.5	3.5
	166.2	15.2	14.6	7.0	2.8	2.8
ICBM1	166.2	15.2	14.6	21.1	17.0	16.9
	13.1	1.2	1.2	1.7	1.3	1.3
	.438	.040	.038	.056	.045	.044
	.136	.946	.878	.800	.826	.827

SIDE ONE COUNTERVALUE STRIKE CHARACTERISTICS

INTERPRETATION OF EACH SET OF ENTRIES

WEAPONS OF TYPE (COLUMN) ALLOCATED AGAINST CITY CLASS (ROW)
WEAPONS OF TYPE (COLUMN) ARRIVING OVER CITY CLASS (ROW)
WEAPONS OFTYPE (COLUMN) IMPACTING ON CITY CLASS
NO. OF 1 MT. FOS. FROM WEAPON TYPE (COLUMN) IMPACTING ON CITY CLASS (ROW)

CITY CLASS	ICBMH	ICBMF	ICBMG	ICBMI	ICBMJ	ICBMK	ICBMA	ICBMB	ICBMC	ICBMD	ICBME	SLBMA
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	30.0	15.0	35.0	35.0	70.0	30.0
3	.0	.0	.0	.0	.0	.0	22.5	10.5	28.0	26.2	49.0	22.5
	.0	.0	.0	.0	.0	.0	4.4	2.1	5.5	5.1	9.6	4.4
	.0	.0	.0	.0	.0	.0	9.8	4.1	6.2	3.2	13.9	6.4

CITY CLASS	SLBMB	SLBMC	BOMBA
	.0	.0	.0
1	.0	.0	.0
	.0	.0	.0
	.0	.0	.0
	.0	.0	.0
2	.0	.0	.0
	.0	.0	.0
	.0	.0	.0
	250.0	200.0	175.0
3	187.5	150.0	131.2
	36.7	29.4	2.8
	55.7	39.4	5.5

SIDE TWO SECOND STRIKE CHARACTERISTICS

INTERPRETATION OF EACH SET OF ENTRIES

NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) BEFORE COUNTERFORCE STRIKE
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) SURVIVING COUNTERFORCE STRIKE
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) ARRIVING OVER CITIES
NO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) IMPACTING ON SIDE ONE CITIES
NO. OF 1 MT. EQS. FROM EACH WEAPON TYPE (COLUMN) IMPACTING ON CITIES

	ICBM3	ICBM2	ICBM1	SLBM1	SLBM2	BOMB1	BOMB2	BOMB3	BOMB4	BOMB5
	600.0	400.0	30.0	150.0	375.0	40.0	125.0	40.0	40.0	50.0
1	600.0	11.3	1.8	150.0	375.0	40.0	125.0	40.0	40.0	50.0
	468.0	9.0	1.3	93.0	225.0	28.8	90.0	28.8	28.8	36.0
	88.0	1.7	.2	17.5	42.3	.0	.1	.0	.0	.0
	74.5	1.7	.6	17.9	31.1	.3	.2	.2	.2	.0

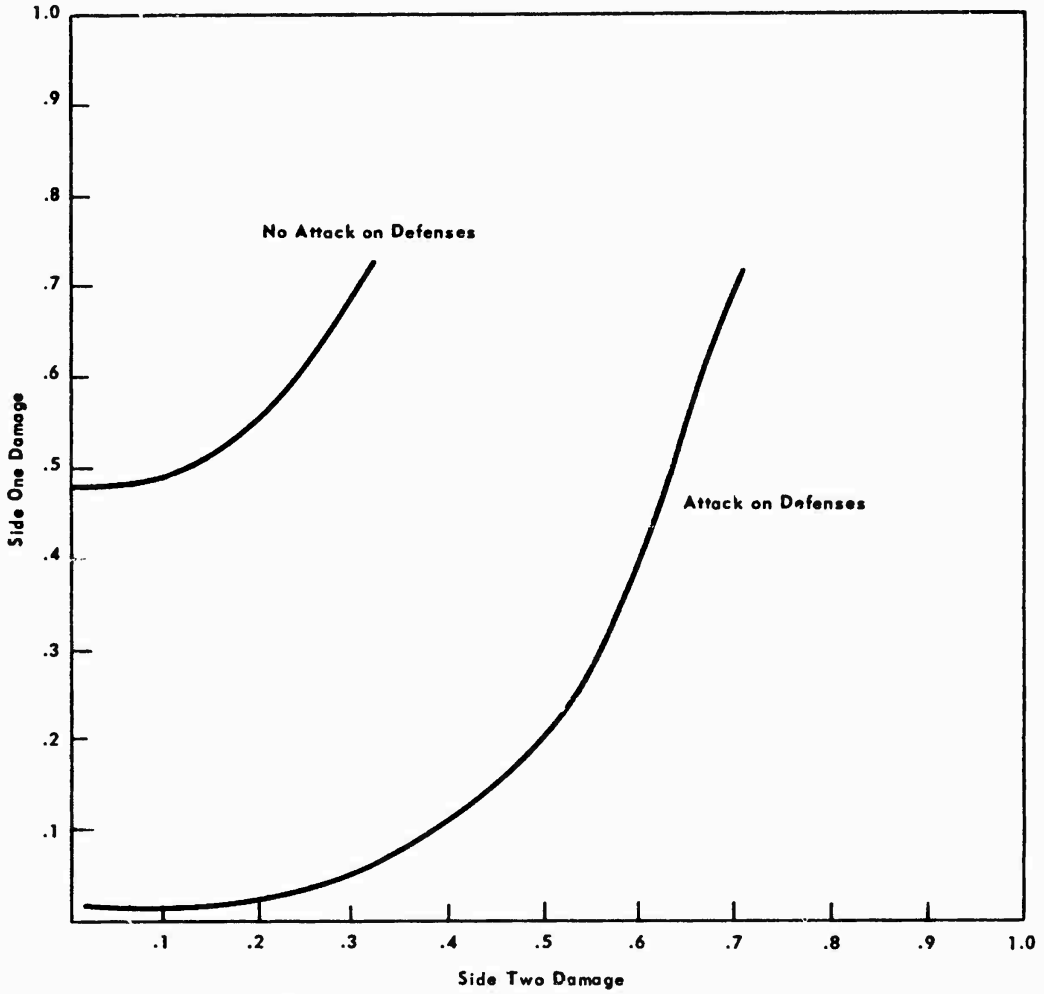


Fig. 1 - Comparison of Damages to Two Nations Using Two Different Offensive Strategies

Appendix A

MATHEMATICAL FORMULATION

Appendix A

MATHEMATICAL FORMULATION

MATHEMATICAL STATEMENT OF THE ALLOCATION OPTIMIZATION MODEL WITH ATTACK ON DEFENSES OPTION

A. General Statement of Model

The mathematical statement of the allocation optimization model is as follows:

$$\text{Minimize } (K_1\bar{\beta} - K_2\beta)$$

over x_{ij}, u_{ik}

subject to

$$\sum_{i=1}^{II} \left(x_{ij} + \sum_{k=0}^{D1-1} u_{ij+k}\right) \le r_1 m_1 \quad \text{for } j=1 \quad D1 \le D$$

$$\sum_{i=1}^{II} \left(x_{ij} + u_{ij+D1-1}\right) \le r_2 m_2 \quad \text{for } j=2,\ldots D-(D1-1) \text{ if } D1<D \quad \text{if } D2\neq 2$$

no constraint if $D1=D$

$$\sum_{i=1}^{II} \left(x_{ij} + \sum_{k=1}^{2} u_{ij+k}\right) \le r_2 m_2 \quad \text{for } j=2 \quad \text{if } D2=2 \text{ and } D1=2$$

$$\sum_{i=1}^{II} x_{ij} \le r_j m_j \quad \text{for } j=D+1,\ldots,J$$

$$\sum_{i=I+1}^{II} x_{ij} \le r_j m_j \quad \text{for } j=J+1,\ldots,JJ$$

$$x_{ij},\ u_{ik} \ge 0$$

where

u_{1k} = number of reliable side 1 weapon type (according to the constraint conventions above) allocated to the kth type side 1 defensive weapon of the ith type resource

x_{1j} = number of reliable side 1 jth type offensive weapons allocated to side 2 ith type resource

m_j = total number of side 1 jth type offensive weapons

r_j = force reliability of side 1 offensive weapon type j

β = fractioned damage to side 2 population

$\bar{\beta}$ = fractioned damage to side 1 population

K_1, K_2 = input parameters determining the strategic goals

I = total number of side 2 CF targets (ICBMs)

II = total number of side 2 targets (ICBMs + Cities)

J = total number of side 1 offensive weapon types with CF and CV capability

JJ = total number of side 1 offensive weapon types

D1 = maximum number of side 2 defensive weapon types that can be attacked by side 1 weapon type 1

D2 = maximum number of side 2 defensive weapon types that can be attacked by side 1 weapon type 2

D = total number of side 2 defensive weapon types that can be attacked by side 1

Note if D=0 there is no attack of defenses, i.e., no u_{1k} variables.

B. Details of Model

First Striker Attack on Second Striker Defenses

The effects of the first striker's attack on the second striker's defenses are modeled in the following way. Let

L_{1k} = total number of defense installations associated with defender type k of resource i

h^{ℓ}_{ik} = total number of defenders of type k of resource i at base ℓ that can be destroyed by the attack (ℓ=1, ...,L_{ik})

g^{ℓ}_{ik} = total number of defenders of type k of resource i at base ℓ that specifically defend the installation

For each side 2 resource i and defensive weapon type k attacked by side 1 a parameter q_{ik} is defined such that the expected number of surviving reliable side 2 defenders from an attack of w side 1 reliable attackers is given by

$$d_{ik} = r'_k \, d'_{ik} \, q_{ik}^{w}$$

The parameters q_{ik} are determined by a least squares fit to a maximum damage curve as follows:

Let w = the number of side 1 reliable attackers

Define for each side 2 resource and defender type k

$$E^{\ell}_{o} = h^{\ell}_{ik}$$

$$\bar{E}_o = \sum_{\ell=1}^{L_{ik}} E^{\ell}_{o}$$

$$\bar{E}_w = \sum_{\ell=1}^{L_{ik}} E^{\ell}_{w} = \bar{E}_{w-1} - \max_{\{\ell=1,\ldots,L_{ik}\}} \left\{ \bar{q}_{ik\ell} \; E^{\ell}_{w-1} \right\}$$

for w=1,...,$\bar{N}$ where $\bar{N}$ is the smallest w such that $\bar{E}_{\bar{N}} < 1$

and

$$\bar{q}_{ik\ell} = \begin{cases} (1 - S'_{ik\ell})(\bar{S}_{ik\ell} \; r'_k + 1 - r'_k) & \text{if } g^{\ell}_{ik} \geq w \\ (1 - S'_{ik\ell}) & \text{if } g^{\ell}_{ik} < w \end{cases}$$

where

$1-S'_{ik\ell}$ = probability side 1 attacker kills base ℓ given it has penetrated the defense of the base

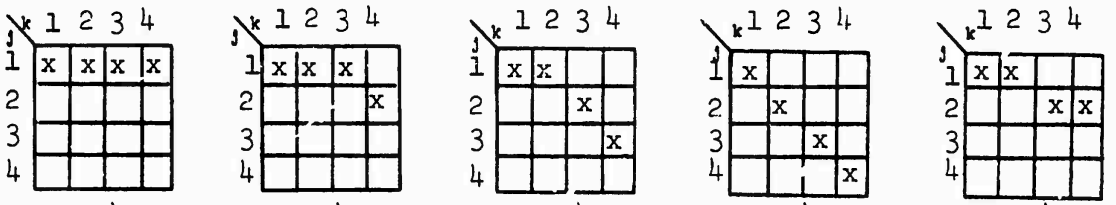
$\bar{S}_{1k\ell}$ = probability side 1 attacker arrives at the base given it encounters side 2 base defender

r'_k = force reliability of side 2 base defenders

The parameters q_{1k} are then defined by the Z that yields the minimum of

$$\min_{Z} \sum_{w=1}^{\bar{N}} (\bar{E}_w - \bar{F}_\ell Z^w)^2 \quad .$$

In order to limit the number of variables, restrictions have been placed on the number of different types of side 1 weapons that can attack side 2 defenses. The following five matrices depict the permissible values of side 1 weapon types j which can attack side 2 defensive types k.



The first type side 1 weapon is the only type which can attack four side 2 defender types. This is the case for the sample problem.

Thus the admissible index value of j in the equation

$$d_{1k} = r'_k \, d'_{1k} \, q_{1k}^{u_{1kj}} \quad \text{where} \quad d'_{1k} = \sum_{\ell=1}^{L_{1k}} h^{\ell}_{1k} \quad (k=1,\ldots,D)$$

(where u_{1kj} is the number of reliable side 1 jth type attackers allocated against defender type k of the ith side 2 resource) is limited to the above five situations. Once D1 and D2 (given D=4) are given the j index value is known and u_{1kj} is designated by u_{1k}.)

Second Striker Defenses

Let d_{ik} = number of reliable side 2 kth type defenders (area or terminal) of side 2 ith type target (geographic area of missile type), k is now permitted to be greater than 1

p_{jk} = single shot survival probability of side 1 jth type attacker when engaged by side 2 kth type defender

x_{ij} = number of reliable side 1 jth type weapons allocated to side 2 ith type target, (geographical area, missile type)

γ_{ijk} = allocation of side 2 kth type defender to side 1 jth type attacker of side 2 ith type target (geographical area, missile type)

JJ = total number of side 1 attacker types,

Note $\sum_{j=1}^{JJ} \gamma_{ijk} = 1.$

Different defense doctrines correspond to different rules for choosing the γ_{ijk}.

Example 1: Consider a "proportional" defense, where the defenders are assigned to attackers in numbers proportional to the fraction of the attack represented by a particular attacker type and to the capability of a defender to bring down a particular attacker.

Then
$$\gamma_{ijk} = \frac{x_{ij}(1-p_{jk})}{\sum_{j=1}^{JJ} x_{ij}(1-p_{jk})} .$$

Example 2: Consider a "uniform" defense, where the defenders are assigned to attackers in numbers proportional to the fraction of the attack represented by a particular attacker only.

Then
$$\gamma_{ijk} = \frac{x_{ij}}{\sum_{j=1}^{JJ} x_{ij}} .$$

RAC

A more general form to use would be

$$\gamma_{i\,jk} = \frac{x_{i\,j}a_{jk}}{\sum_{j=1}^{JJ} x_{i\,j}a_{jk}} \qquad a_{jk} = (1-p_{jk}) \text{ in example 1,}$$

$$a_{jk} = 1 \text{ in example 2.}$$

The a_{jk} are constants to be read in (or calculated) at the beginning of the program.

The fraction of side 1 jth type attackers of side 2 ith type targets surviving the defenses is then given by

$$F_{i\,j} = \prod_{k=1}^{K} p_{ik}^{\left(\frac{\gamma_{i\,jk}d_{ik}}{x_{i\,j}}\right)} = \exp\left(\sum_{k=1}^{K} \frac{\gamma_{i\,jk}d_{ik}}{x_{i\,j}} \ell n\ p_{jk}\right)$$

In the general form this reduces to

$$F_{i\,j} = \exp\left(\sum_{k=1}^{K} \frac{a\ \ a_{jk}d_{ik}}{\left(\sum_{j=1}^{JJ} x_{i\,j}a_{jk}\right)} \ell n\ p_{jk}\right),$$

where K = total number of side 2 defender types.

Retaliators Surviving the First Strike

The number of side 2 mth type weapons retaliating on side 1 is

$$y_m = \bar{r}_m n_m S_m \qquad m = 1,\ldots,M,$$

where

$\bar{r}_m$ = reliability of side 2 mth type retaliator,

n_m = number of side 2 mth type weapon prior to side 1 CF attack,

S_m = fraction of side 2 mth type weapon surviving side 1 CF attack,

$$= \prod_{j=1}^{J} s_{m\,j}^{\left(\frac{x_{m\,j}F_{n\,j}e_j}{n_m}\right)} \qquad m = 1,\ldots,I$$

where y_m = number of side 2 mth type weapons retaliating on side 1.

This done, constants $\bar{a}_{mn}$ can be read in, as was done for the side 2 defenses such that

$$\bar{Y}_{\ell mn} = \frac{y_{\ell m}\bar{a}_{mn}}{\sum_{m=1}^{M} y_{\ell m}\bar{a}_{mn}}$$

represents the performance of side 1 defenses, whether uniform or proportional. The fraction of side 2 mth type retaliators on side 1 ℓth type targets is then given by

$$\bar{F}_{\ell m} = \exp\left(\sum_{n=1}^{N} \frac{\bar{a}_{mn}\bar{a}_{\ell n}}{\sum_{m=1}^{M} b_{\ell m} y_m \bar{a}_{mn}} \ln \bar{p}_{mn}\right),$$

where N = total number of side 1 defender types.

In summary it should be pointed out that the single shot survival probabilities (1) p_{jk}, (2) s_{ij}, and (3) $\bar{p}_{mn}$ are instrumental in modeling the interaction of (1) the first striker offense with the second striker defense, (2) the first striker offense with the second striker CV targets, and (3) the second striker offense with the first striker defense, respectively. Of course information on the p_{ik} and $\bar{p}_{mn}$ may then be or not be used in determing the defense allocation doctrine constants a_{jk} and $\bar{a}_{mn}$.

Damage Determination

The number of 1MT equivalents delivered on side two's ith type CV target is given by

$$EQ_i = \sum_{j=1}^{J} F_{ij} x_{ij} k_j + \sum_{j=J+1}^{JJ} F_{ij} x_{ij} k_j \qquad i = 1, \ldots, II\text{-}I$$

The number of 1MT equivalents delivered on side one's ℓth type CV target is

$$\overline{EQ}_\ell = \sum_{n=1}^{M} \bar{F}_{\ell n} y_{\ell n} \bar{k}_n$$

As noted previously the fraction damage to side two's ith type CV target is

$$\beta_i = 1 - (1 + A_i\sqrt{EQ_i}) \exp(-A_i\sqrt{EQ_i})$$

The fraction damage to side one's ℓth type CV target is

$$\bar{\beta}_\ell = 1 - (1 + \bar{A}_\ell\sqrt{\overline{EQ}_\ell}) \exp(-\bar{A}_\ell\sqrt{\overline{EQ}_\ell})$$

The total fraction population loss to side two is

$$\beta = \frac{1}{TOTP} \sum_{i=1}^{II-I} P_i \beta_i$$

and to side one

$$\bar{\beta} = \frac{1}{\overline{TOTP}} \sum_{\ell=1}^{L} \bar{P}_\ell \bar{\beta}_\ell$$

where TOTP = total population of side two,

$\overline{TOTP}$ = total populations of side one,

P_i = population in side two's its area,

$\bar{P}_\ell$ = population in side one's ℓth area.

C. Remarks Concerning the First and Second Partial Derivatives With Respect to Allocations Against the Defenses

The first and second partial derivatives of the objective function with respect to side 2 defensive variable d_{ik} have been evaluated in a prior model (see RAC-CR-43). The same evaluation is made in the present

model even though the d_{ik} are not independent variables of the current model. The following equations apply in evaluating derivatives with respect to allocations against the defense u_{ik} in terms of known derivatives with respect to d_{ik}. These equations are used by the subroutines GRAD1 and MATRIX.

$$d_{ik} = r'_k \, d'_{ik} \, q_{ik}^{\,u_{ik}}$$

$$= r'_k \, d'_{ik} \, e^{b_{ik}u_{ik}} \quad \text{where} \quad q_{ik} = e^{b_{ik}}$$

$$\frac{\partial d_{ik}}{\partial u_{ik}} = b_{ik} \, d_{ik}$$

$$\frac{\partial^2 d_{ik}}{\partial u_{ik}^2} = b_{ik}^2 \, d_{ik}$$

For any function f we have

$$\frac{\partial f}{\partial u_{ik}} = \frac{\partial f}{\partial d_{ik}} (b_k \, d_{ik})$$

$$\frac{\partial^2 f}{\partial u_{jn} \partial u_{ik}} = \frac{\partial^2 f}{\partial d_{jn} \partial d_{ik}} \; (b_{jn} d_{jn}) \; (b_{ik} d_{ik}) + \frac{\partial f}{\partial d_{ik}} \; \delta_{ij} \; \delta_{kn} \; b_{ik}^2 \; d_{ik}$$

$$\frac{\partial^2 f}{\partial x_{jn} \partial u_{ik}} = \frac{\partial^2 f}{\partial x_{jn} \partial d_{ik}} \; (b_{ik} d_{ik})$$

Appendix B

FORTRAN LISTING OF PROGRAM WITH COMMENTS

```
      SUBROUTINE READIN
C
C ---- THIS SUBROUTINE READS IN THE INPUT CONSTANTS OF THE PROBLEM --
C
      COMMON/SHAPE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
      COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IED,IEN
     1,IEU,IEX1,IEYEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NOOFFS,NN,NU1,NU2,NU3
     2,IB1,ND ,NU4,NU5,NU6,NU7,NU8,ND1,ND2
      COMMON/TWO/AA(6),AAB(2),FPOP(6),FPOPB(2),DL(9,7),ENL(10),RB(10),
     1EKB(10),TITLE2(10),P(15,7) ,AB(10,15),B(2,10),DE(2,10),EM(15),
     2E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),UU(15)
      COMMON/THREE/PREFER,PREFIN,PREINC,PREBET,B1(9,5),RD(5)
      COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
      COMMON/FIVE/XX(9,15),D(9,7),EN(10),O(9,5),U(9,7)
      COMMON/SIX/Z(9,7) ,ZB(2,10),F(9,15),S(10),FB(2,10),BETA(6),Y(6),
     1BETAB(2),YB(2),BETB,BET
      COMMON/SEVEN/DFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DBX(6,15),
     1DYD(6,7),DPD(6,7),BETPP(2),BETPP(6),BETBPP(2)
      COMMON/EIGHT/DSX(5,6),DSD(5,7),        DF1X(10,5,6),DF2X(10,5,6),
     1DF1D(10,5,7),DF2D(10,5,7),             DYBX(2,5,6),DYBD(2,5,7)
      COMMON/NINE/DBBX(5,6),DBBD(5,7)
      COMMON /OUTIN/ PPB(20),ZN1(20),ZN2(20),RAT(10)
      COMMON /EQAL/ H,H1,M7
      DIMENSION W2(20),PSI(20),        W1(20),        CEP(20),FFP(20),
     CRL(20,20)
      DIMENSION DCAP(20),ACAP(20),EJN(20),QBAR(20),SPRIME(20),EBAR(1000)
      DIMENSION HARD(20),PSUR(5)
C
C ---DATA FOR THE ALLOCATION MODEL
C---SEE DESCRIPTION OF INPUT DATA FOR DETAILS ---
      WRITE (6,655)
      WRITE (6,660)
      WRITE(6,250)
250   FORMAT (//45X,37H**INPUT CONDITIONS FOR THIS RUN **    )
C
C --(3-1)-PROBLEM SIZE AND OPTION CARDS ---
C
      READ(5,1) NI,NII,NM,NJ,NJJ,NK,NL,NN,ND,NDEFS,IB1,NU1,NU3,NU4
      READ(5,1) ND1,ND2
C
C ----- USER OPTIONS -----
C ***** IF NU1=1 PROGRAM SELECTS STARTING FEASIBLE POINT ********
C ***** IF NU3=1 A PRINTOUT OF ALL POINTS IS GIVEN DURING THE SOLUTION
C **** NU4 IS THE TOTAL NUMBER OF STRATEGIES CONSIDERED WHERE RATIO
C *****(K2/K1) EQUALS RAT(I) *****
C ----- NO LESS OR EQUAL ZERO   NO ATTACK ON DEFENSES -----
C
      IF(ND.GT.0) WRITE(6,246)
  246 FORMAT(/48X,31HATTACK ON DEFENSES OPTION USED    )
      IF(ND.LE.0) WRITE(6,247)
  247 FORMAT(/48X,29HSTANDARD DEFENSE OPTION USED  )
      WRITE(6,25)NDEFS,IB1,   NU1,NU3,NU4
       WRITE(6,3) NI, NII, NM, NK, NJ, NL, NJJ, NN
      WRITE(6,700)NC,NC1,ND2
  700 FORMAT(1HC,5X,5I5)
       NI1 = NI + 1
       NI2 = NII - NI
```

```
      NIIJ = NII * NJ
      NJ1 = NJ + 1
      IF(NJJ.EQ.NJ) NJ1=NJ
      NJ2 = NJJ - NJ
      IEX = NI * NJ + NI2 * NJJ
      IEX1 = IEX + 1
      IF(ND.LT.0) ND=0
      IED = IEX + NII * ND
      I1 = ND
      IF(ND2.NE.2.AND.ND.GT.0) I1= ND - ( ND1 - 1 )
      IF(ND2.EQ.2.AND.ND.GT.0) I1= 2
      I2 = NJ
      I3 = NJJ
      MC = I3
      NV = IED
      MZ = 0
C
C --(3-2)-DAMAGE CURVE FIT PARAMETERS AND FRACTIONAL POPULATIONS
C
      READ(5,2) (AA(I),I=1,NI2)
      WRITE(6,5)
      WRITE(6,4) (AA(I),I=1,NI2)
      READ(5,2) (AAB(I),I=1,NL)
      WRITE(6,6)
      WRITE(6,4) (AAB(I),I=1,NL)
      READ(5,2) (FPOP(I),I=1,NI2)
      WRITE(6,7)
      WRITE(6,4) (FPOP(I),I=1,NI2)
      READ(5,2) (FPOPB(I),I=1,NL)
      WRITE(6,8)
      WRITE(6,4) (FPOPB(I),I=1,NL)
      WRITE (6,655)
      WRITE (6,295)
295   FORMAT (//40X,53H          FORCE STRUCTURE AND WEAPONS CHARACTERIST
     1ICS )
      WRITE(6,9600)
      DO 109 I=1,NI
C
C --(3-3)-SIDE TWO OFFENSIVE SYSTEMS AND SINGLE SHOT SURVIVAL PROBS.
C ------AGAINST SIDE ONE DEFENSIVE WEAPON TYPES
C
      READ(5,91)  EN(I),RB(I),W2(I),PSI(I),ZN2(I),TITLE2(I)
      READ(5,2) ( PB(I,J),J=1,NN)
  109 CONTINUE
      DO 111 I=NI1,NM
C
C --(3-3) CONTINUED
C
      READ(5,10) EN(I),RB(I),W2(I),ZN2(I),TITLE2(I)
      READ(5,2) ( PB(I,J),J=1,NN)
  111 CONTINUE
      DO 736 M=1,NM
C
C -----COMPUTE DEFENSE ALLOCATION CONSTANTS FOR SIDE ONE ----------
C
      IF(IB1-2)751,733,735
  751 DO 752 N=1,NN
  752 AB(M,N) = 1. - PB(M,N)
```

```
      GO TO 736
  733 DO 734 N=1,NN
  734 AB(M,N) = 1.
      GO TO 736
  735 READ(5,2)(AB(M,N),N=1,NN)
  736 CONTINUE
      WRITE(6,211)
  211 FORMAT(1HC,43X,17HOFFENSIVE SYSTEMS)
      WRITE(6,216)
  216 FORMAT(1HC,39X, 8HSIDE TWO)
      WRITE(6,201)
  201 FORMAT(1HC,4X,76HTYPE   SYSTEM   INVENTORY   FORCE REL.   WARHEAD
     1YIELD   NO. OF WH   P.S.I. )
  206 FORMAT(1H ,5X,I2,4X,A6,3X,F8.2,6X,F5.4,9X,F8.3,7X,F4.0,6X,F6.2)
      DO 207 I=1,NI
  207 WRITE(6,206)I,TITLE2(I),EN(I),RB(I),W2(I),ZN2(I),PSI(I)
      DO 212 I=NI1,NM
  212 WRITE(6,206)I,TITLE2(I),EN(I),RB(I),W2(I),ZN2(I)
      DO 115 M=1,NM
      DO 115 N=1,NN
  115 CB(M,N) = AB(M,N) * ALOG(PB(M,N))
      WRITE(6,221)
  221 FORMAT(1HC,39X, 8HSIDE ONE)
      WRITE(6,226)
  226 FORMAT( /5X,108HTYPE   SYSTEM   INVENTORY   FORCE REL.   WARHEAD Y
     1IELD   NO. OF WH   NO. IND. TAR. WH   NO. CLUSTER WH   CEP)
  231 FORMAT(1H ,5X,I2,4X,A6,3X,F8.2,6X,F5.4,9X,F8.3,7X,F4.0,11X,F4.0,14
     1X,F4.0,9X,F5.2)
      DO 131 I=1,NJ
C
C --(3-4)-SIDE ONE OFFENSIVE SYSTEMS AND SINGE SHOT SURVIVAL ERORS.
C ------AGAINST SIDE TWO DEFFNSIVE WEAPON TYPES
C
      READ(5,94)EM(I),RBB(I),E(I),W1(I),CEP(I),FPP(I),ZN1(I),TITLE1(I)
      READ(5,2)(P(I,J),J=1,NK)
      WRITE(6,231)I,TITLE1(I),EM(I),RBB(I),W1(I),ZN1(I),E(I),FPP(I),CEP(
     1I)
  131 CONTINUE
      DO 132 I=NJ1,NJJ
C
C --(3-4) CONTINUED
C
      READ(5,91) EM(I),RBB(I),E(I),W1(I),ZN1(I),TITLE1(I)
      READ(5,2) ( P(I,J),J=1,NK)
      WRITE(6,231)I,TITLE1(I),EM(I),RBB(I),W1(I),ZN1(I),E(I)
  132 CONTINUE
      DO 136 I=1,NJJ
C
C -----COMPUTE DEFENSE ALLOCATION CONSTANTS FOR SIDE TWO ----------
C
      IF (NDEFS - 2) 151,133,135
  151 DO 152 J=1,NK
      AN(I,J) = 1. -  P(I,J)
  152 CONTINUE
      GO TO 136
  133 DO 134 J=1,NK
      AN(I,J) = 1.
  134 CONTINUE
```

```
      GO TO 136
135   READ(5,2) (AN(I,J),J=1,NK)
      WRITE(6,18)
      WRITE(6,4) (AN(I,J),J=1,NK)
 136  CONTINUE
      DO 2?4 I=1,NI
      DO 2?4 J=1,NJ
      RL(I,J)=2.8*(W1(J)**?.333)*(PSI(I)-7.37)**(-?.352)
      SS(I,J)=?.5**((FPP(J))*(RL(I,J)/CEP(J))**2)
C
C -----COMPUTE SINGLE SHOT SURVIVAL PROPS. FOR SIDE TWO HARDSITES VS.
C ------SIDE ONE OFFENSE --------
C *** IF SINGLE SHOT SURV. PROB. IS LESS THAN .01 INCREASE IT BY .01  **
      IF(SS(I,J).LT.1.?E-2) SS(I,J) = SS(I,J) + .?1
C
 2?4 CONTINUE
395   FORMAT (//21X,76HSINGLE SHOT SURVIVAL PROBABILITIES (SIDE TWO ICBM
     1S VS SIDE ONE MISSILES) ***/5X,14HSIDE TWO ICBMS,26X,26HSIDE ONE M
     2ISSILES (ACROSS)/9X,6H(DOWN))
4??   FORMAT (7X,A6,12(4X,F6.4))
525   FORMAT ( /15X,12(4X,A6))
      WRITE (6,655)
      WRITE(6,9???)
      WRITE (6,395)
      WRITE (6,525) (TITLE1(J),J=1,NJ)
      DO 2?5 I=1,NI
 2?5 WRITE (6,4??) TITLE2(I),(SS(I,J),J=1,NJ)
 795 FORMAT (//21X,76HSINGLE SHOT SURVIVAL PROBABILITIES (SIDE TWO OFFS
     1. VS SIDE ONE DEFORS. ) ***/5X,14HSIDE TWO OFFS.,26X,26HSIDE ONE D
     2EFORS.  (ACROSS)/9X,6H(DOWN))
      WRITE(6,795)
      WRITE(6,625)(N,N=1,NN)
      DO 8?5 M=1,NM
 8?5 WRITE(6,4??)TITLE2(M),(FB(M,N),N=1,NN)
      DO 141 J=1,NJJ
      IF(W1(J).LE.1.?) EK(J)=ZN1(J)*W1(J)**?.667
      IF(W1(J).GT.1.?) EK(J)=ZN1(J)*W1(J)**.5?
 141  CONTINUE
      DO 142 J=1,NM
      IF(W2(J).GT.1.?) EKB(J)=ZN2(J)*W2(J)**?.5?
      IF(W2(J).LE.1.?) EKB(J)=ZN2(J)*W2(J)**?.667
 142  CONTINUE
      WRITE(6,495)
 495 FORMAT (//21X,76HSINGLE SHOT SURVIVAL PROBABILITIES (SIDE ONE ICBM
     1S VS SIDE TWO DEFORS. ) ***/5X,14HSIDE ONE ICBMS,26X,26HSIDE TWO D
     2EFORS.  (ACROSS)/9X,6H(DOWN))
 625 FORMAT ( /12X,12(4X,I6))
      WRITE(6,625)(K,K=1,NK)
      DO 6?6 J=1,NJJ
 6?6 WRITE(6,4??) TITLE1(J),(P(J,K),K=1,NK)
      DO 155 I=NI1,NM
 155 S(I) = RF(I)
      DO 16? I=1,NI
      DO 16? J=1,NJ
      FLNS(I,J) =  E(J) * ALOG(SS(I,J))
16?   CONTINUE
      DO 165 J=1,NJJ
      DO 165 K=1,NK
```

```
  165 C(J,K) = AN(J,K) * ALOG(P(J,K))
      WRITE(6,900)
C
C --(3-5)- SIDE ONE OFFENSIVE INVENTORY USED FOR OTHER TARGETS
C
       READ(5,2) (UU(I),I=1,NJJ)
       WRITE(6,20)
       WRITE(6,4) (UU(I),I=1,NJJ)
      DO 143 J=1,NJJ
      IF( UU(J).LT.EM(J) ) EM(J) = EM(J) - UU(J)
  143 CONTINUE
      DO 147 J=1,NJJ
  147 EM(J)=RDB(J)*EM(J)
      WRITE(6,900)
      NU8 = 1
      WRITE(6,797)
C
C --(3-6)-STRATEGIES TO BE INVESTIGATED (RATIO OF K2/K1)
C
      READ(5,2)(RAT(I),I=1,10)
      DO 799 I=1,NU4
  799 WRITE(6,798)I,RAT(I)
  797 FORMAT( //10X,28HRATIOS SELECTED FOR STRATEGY/15X,21HCASE      VALU
     1E(K2/K1))
  798 FORMAT( 16X,I2,5X,E12.4)
      IF(   RAT(1).GT.1.E+7)PREBET = 100.
      IF(   RAT(1).GT.1.E+7)PREFER=0.
      IF(   RAT(1).GT.1.E+7) GO TO 937
      PREFER = 100.
      PREBET = PREFER * RAT(1)
  937 CONTINUE
      WRITE (6,655)
      WRITE(6,900)
  241 FORMAT(1HC,43X,17HDEFENSIVE SYSTEMS)
      WRITE(6,241)
      WRITE(6,221)
       WRITE(6,15)
       DO 130 I=1,NL
C
C --(3-7)-SIDE ONE RELIABLE DEFENSIVE WEAPONS SYSTEMS INVENTORY FOR
C ------POPULATION CLASS L ------
C
       READ(5,2) (DP(I,J),J=1,NN)
       WRITE(6,4)(DE(I,J),J=1,NN)
  130  CONTINUE
      WRITE(6,216)
      WRITE(6,24)
C
C --(3-8)-SIDE TWO OFFENSIVE SYSTEMS FORCE RELIABILITY --
C
      READ(5,2) (RD(K),K=1,NK)
      WRITE(6,4)(RD(K),K=1,NK)
      IF(ND.EQ.NK) GO TO 253
      IF(ND.GT.0.AND.ND.LT.NK) ND3 = ND + 1
      IF(ND.LE.0) ND3 = 1
      DO 263 I=1,NII
C
C --(3-9)-SIDE TWO DEFENSIVE WEAPONS INVENTORY FOR SIDE TWO WEAPONS
```

```
C ------NOT ATTACKED BY SIDE ONE --------
C
  263 READ(5,2)(DL(I,K),K=ND3,NK)
      IF(ND.LE.0) GO TO 107
C
C --(3-10)-SIDE ONE OFFENSIVE WEAPON SURVIVAL PROBABILITY VS. SIDE TWO
C ------DEFENSE INSTALLATION DEFENDERS ---
C
  253 READ(5,2) (PSUR(K),K=1,ND)
      WRITE(6,971)
  971 FORMAT(/10X,49HSURVIVAL PROB. OF SIDE ONE OFFS. VS. BASE DEFORS.)
      WRITE(6,4)(PSUR(K),K=1,ND)
C
C **** COMPUTATION OF MAXIMUM DAMAGE CURVE **************
C
      C1 = ( SQRT(5.) - 1.) / 2.
      C2 = 1. - C1
      DO 500 K=1,ND
      DO 500 I=1,NII
      LL =1
      WRITE(6,803)I,K
C
C --(3-11-1)-SIDE TWO RESOURCE I NO OF DEFENSE INSTALLATIONS
C
      READ(5,1) NBASE,IFIT,LL0,LL1
C
C ----- USER FITS CURVE  OVER INTERVAL (LL0,LL1) IF IFIT = 1
C
      IF(NBASE.LE.0) Q(I,K) = 1.
      IF(NBASE.LE.0)DL(I,K) = .01
      IF(NBASE.LE.3) GO TO 500
      NIK = NBASE
      WRITE(6,256) K, I, NIK
  256 FORMAT(1HO,4X,15HDEF. WEAP. TYPE,I3,31H  REGION OR CITY CLASS DEFE
     1NDED,I3,38H   NO. OF BASES DEFENDED BY WEAP. TYPE,I3)
      IF(IFIT.EQ.1) LL=LL0
      IF(IFIT.EQ.1) NFIN = LL1
      IF(IFIT.EQ.1)WRITE(6,977)LL0,LL1
  977 FORMAT(/10X,47HUSER CHOOSES TO FIT CURVE USING STARTING POINT ,I3
     1 ,15H AND END POINT ,I4)
      SUM = 0.
      WRITE(6,261)
  261 FORMAT(1HO,9X,106HBASE NO.   HARDNESS(PSI)   NO. OF DEFORS. OF BAS
     1E   NO. DEFORS. AT BASE   DEFENDED BASE    UNDEFENDED BASE/84X,31H
     2SURVIVAL PROB.   SURVIVAL PROB.)
      DO 210 J=1,NIK
C
C --(3-11-2)-SIDE TWO DEFENSE INSTALLATION INFORMATION
C
      READ(5,2) HARD(J),DCAP(J),ACAP(J)
      TERM = 2.8 * (W1(K)**.333) * ( HARD(J)-7.37) ** (-0.352)
      SPRIME(J) = .5 ** ((FFP(K)) * ( TERM / CFP(K)) **2)
      QBAR(J) = (1. - SPRIME(J)) * ( RD(K) * (PSUR(K) -1.) + 1.)
      IF(ACAP(J).LT.1.) QBAR(J) = 1. - SPRIME(J)
      EJN(J) = DCAP(J)
      VAL=1-QBAR(J)
      WRITE(6,266) J,HARD(J),ACAP(J),DCAP(J),VAL,SPRIME(J)
  266 FORMAT(1H ,15X,I2,10X,F6.2,12X,F5.1,16X,F6.1,14X,F5.4,12X,F5.4)
```

```
  210 SUM = SUM + EJN(J)
      EBAR0 = SUM
      DL(I,K) = SUM
      DO 230 N=1,1000
      BIG = 0.
      DO 220 J=1,NIK
      TERM = EJN(J) * QBAR(J)
      IF(TERM.GT.BIG) JMAX = J
      IF(TERM.GT.BIG) BIG = TERM
  220 CONTINUE
      EBAR(N) = SUM - BIG
      EJN(JMAX) = EJN(JMAX) - BIG
      SUM = EBAR(N)
      ACAP(JMAX) = ACAP(JMAX) - 1.
      IF(ACAP(JMAX).EQ.0.)QBAR(JMAX) = 1. - SPRIME(JMAX)
      IF(IFIT.EQ.1) GO TO 230
      IF(SUM.LT.1.) NFIN = N
      IF(SUM.LT.1.) GO TO 240
  230 CONTINUE
      NFIN = 1000
      IF(IFIT.EQ.1) NFIN=LL1
C
C **** LEAST SQUARES FIT TO MAX. LAM. CURVE USING FIBONACCI SEARCH *****
C
  240 TU = 1.
      TL = 0.
      TB = C1
      TA = C2
      ISET = 1
      VALB = 0.
      DO 305 N=L0,NFIN
  305 VALB = VALB + ( EBAR0 * TB**N - EBAR(N))**2
      DO 410 L=1,60
      IF(ISET-2) 340,310,310
  310 VALB = 0.
      DO 330 N=L0,NFIN
  330 VALB = VALB + ( EBAR0 * TB**N - EBAR(N))**2
      IF(ISET-2)340,360,340
  340 VALA = 0.
      DO 350 N=L0,NFIN
  350 VALA = VALA + ( EBAR0 * TA**N - EBAR(N))**2
  360 IF(VALA - VALB) 370,390,380
  370 TU = TB
      TB = TA
      TA = TL + C2 * (TU - TL)
      VALB = VALA
      ISET = 1
      GO TO 410
  380 TL = TA
      TA = TB
      TB = TL + C1 * (TU - TL)
      VALA = VALB
      ISET = 2
      GO TO 410
  390 TL = TA
      TU = TB
      IF (ABS(TL / TU - 1.).LE.1.E-3) GO TO 450
      TA = TL + C2 * (TU - TL)
```

```
      TB = TL + C1 * (TU - TL)
      ISET = 3
  41  CONTINUE
  42  FORMAT(1H0,6E16.8)
  45  Q(I,K) = (TL + TU)/ 2.
      WRITE(6,271)
 271  FORMAT(1H0,38X,51HEXPECTED NO. OF SURVIVING DEFENDERS VS. ATTACK S
     1IZE/38X,48HNO. ATTACKERS   EXP. NO. SURV.   CURVE FIT VALUE)
      DO 470 N= 1,NFIN
      VAL = EBAR0 * Q(I,K)**N
 470  WRITE(6,276)N,EBAR(N),VAL
 276  FORMAT(1H ,43X,I3,9X,F9.2,9X,F9.2)
 500  CONTINUE
 107  WRITE(6,9)
      WRITE(6,625)(K,K=1,NK)
      DO 806 I=1,NII
 806  WRITE(6,825)I,(DL(I,K),K=1,NK)
      DO 100 I=1,NII
      DO 100 K=1,NK
      DL(I,K) = RD(K) * DL(I,K)
 100  Q(I,K) = DL(I,K)
      IF(ND.LE.0) GO TO 1000
      DO 105 I=1,NII
      DO 105 K=1,ND
 105  B1(I,K) = ALOG(Q(I,K))
      WRITE(6,193)
 193  FORMAT(1H0, 43HCURVE FIT VALUES FOR Q(I,K), K(ACCROSS) , I(DOWN))
      WRITE(6,625)(K,K=1,ND)
 825  FORMAT( 7X,I6,12(4X,F6.1))
 925  FORMAT( 7X,I6,12(4X,F6.4))
      DO 841 I=1,NII
 841  WRITE(6,925)I,( Q(I,K),K=1,ND)
      WRITE(6,9000)
1000  IF(NU1.EQ.1) CALL STARTB
      RETURN
    1 FORMAT(14I5)
2       FORMAT(10F8.0)
3       FORMAT(1H0,4X,9HSIDE 2 --,I7,11H OF TARGETS,10X,I7,8H TARGETS,
     1         9X,I7,13H WEAPON TYPES,I7,15H DEFENDER TYPES //
     2         5X,9HSIDE 1 --,I7,21H OF + OV WEAPON TYPES,I7,
     3         17H GEOGRAPHIC AREAS,I7,13H WEAPON TYPES,I7,
     4         15H DEFENDER TYPES)
4       FORMAT( 8X,10F12.4)
5       FORMAT(1H0,4X,39HFITTING CONSTANTS FOR SIDE 2 POPULATION)
6       FORMAT(1H0,4X,39HFITTING CONSTANTS FOR SIDE 1 POPULATION)
7       FORMAT(1H0,4X,41HFRACTION OF SIDE 2 POPULATION IN ITH AREA)
8       FORMAT(1H0,4X,41HFRACTION OF SIDE 1 POPULATION IN LTH AREA)
9       FORMAT(1H0,4X,47HNUMBER OF K TH TYPE SIDE 2 DEFORS. (ACCROSS) OF,
     123HI TH TYPE TARGET (DOWN))
   10   FORMAT(4F8.0 ,A6)
   11 FORMAT(1H0,4X,11HSIDE 2 TYPE,I2,22H WEAPON --  NUMBER    ,F7.2,14H
     1   RELIABILITY,F7.4,16H   WARHEAD YIELD,  F7.2,              18H
     2  NO. OF WARHEADS,F7.2/ 5X,7HNAME - ,A6)
12      FORMAT(1H0,4X,44HSINGLE SHOT SURVIVAL PROBABILITY ENGAGED BY ,
     1                24HSIDE 1 NTH TYPE DEFENDER)
13      FORMAT(1H0,4X,35HSIDE 1 DEFENSE ALLOCATION CONSTANTS)
14      FORMAT(1H0,4X,37HSIDE 2 OFFENSIVE ALLOCATION CONSTANTS)
15      FORMAT(1H0,4X,44HNUMBER OF RELIABLE SIDE 1 DEFENDERS OF SIDE ,
```

```
     1                12H1 LTH TARGET)
   16 FORMAT(1HC,4X,11HSIDE 1 TYPE,I2,24H WEAPON --NO. OF WEAPONS,F7.2,
     114H   RELIABILITY,F7.4,34H   NO. OF IND. TARGETABLE WARHEADS,F7.2,
     216H   WARHEAD YIELD,F7.2/5X,7HNAME - ,A6,18H   NO. OF WARHEADS,F7.
     32)
   17    FORMAT(1HC,4X,48HSINGLE SHOT SURVIVAL PROB. WHEN ENGAGED BY SIDE
     1               ,19H2 KTH TYPE DEFENDER)
   18    FORMAT(1HC,4X,35HSIDE 2 DEFENSE ALLOCATION CONSTANTS)
   19    FORMAT(1HC,4X,46HSINGLE SHOT SURVIVAL PROB. OF SIDE 2 MTH TYPE
     1               47HRETALIATOR ATTACKED BY SIDE 1 JTH TYPE ATTACKER)
   20    FORMAT(1HC,4X,47HNUMBER OF EACH SIDE 1 WEAPON ASSIGNED TO OTHER ,
     1               16HMILITARY TARGETS)
   21    FORMAT(1HC,4X,6HPREFER,F7.2 ,7H PREFIN,F7.2 ,7H PREINC,F7.2 ,
     1               4H PHI,F7.4 ,7H PREBET,F7.2 ,7H TL,F7.2 ,4H EPS,
     2F7.4)
   23 FORMAT(1HC,4X,32H NO. SIDE 2 OFFS. TYPE I WEAPONS)
   24  FORMAT(1HC,4X,40HRELIABILITY OF  KTH TYPE SIDE 2 DEFENDER)
   25 FORMAT(1HJ,4X,5HNDEFS,I2,9H     IB1=,I2,6H  NU1=,I2,6H  NU3=,I2,6H
     1  NU4=,I2)
  655 FORMAT (1H1)
  660 FORMAT (29X,62H**********STRATEGIC WEAPONS EXCHANGE MODELS (SWEM)
     1**********,//45X,34H    ALLOCATION OPTIMIZATION MODEL )
   91 FORMAT(5E8.0 ,A8)
   94  FORMAT(7E8.0 ,A8)
   92 FORMAT(1HC,4X,11HSIDE 2 TYPE,I2,22H WEAPON --  NUMBER    ,F7.2,14H
     1   RELIABILITY,F7.4,16H   WARHEAD YIELD,F7.2,9H   P.S.I.,F7.2,18H
     2  NO. OF WARHEADS,F7.2/ 5X,7HNAME - ,A6)
   93 FORMAT(1HC,4X,11HSIDE 1 TYPE,I2,24H WEAPON --NO. OF WEAPONS,F7.2,
     114H   RELIABILITY,F7.4,34H   NO. OF IND. TARGETABLE WARHEADS,F7.2,
     216H   WARHEAD YIELD,F7.2/5X,7HNAME - ,A6,9H   C.E.P.,F7.2,26H   NO
     3. OF CLUSTER WARHEADS,F7.2,18H   NO. OF WARHEADS,F7.2)
  803 FORMAT( 1HC,5X,14I5)
 9000 FORMAT( //132H ************************************************
     1**********  **********
     2**********)
      END
```

```
      SUBROUTINE RESTNT(MT,VAL)
C
C ---- THIS SUBROUTINE GIVES THE VALUES OF THE CONSTRAINTS AND OBJECT-
C -----IVE FUNCTION -----
C
      COMMON/SHARE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
      COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IED,IEN
     1,IEU,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NCOEFS,NN,NU1,NU2,NU3
     2,IB1,ND ,NU4,NU5,NU6.NU7,NU8,ND1,ND2
      COMMON/TWO/AA(6),AAB(2),FPOP(6),FPOPB(2),DL(9,7),ENL(10),RB(10),
     1EKB(10),TITLE2(10),P(15,7) ,AB(10,15),B(2,10),DB(2,10),EM(15),
     2E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),LU(15)
      COMMON/THREE/PREFER,PREFIN,PREINC,PREBET,B1(9,5),RD(5)
      COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
      COMMON/FIVE/XX(9,15),D(9,7),EN(10),C(9,5),U(9,7)
      COMMON/SIX/Z(9,7) ,ZB(2,10),F(9,15),S(10),FB(2,10),BETA(6),Y(6),
     1BETAB(2),YB(2),BETB,BET
      COMMON/SEVEN/DFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DBX(6,15),
     1DYD(6,7),DBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
      COMMON/EIGHT/DSX(5,6),DSD(5,7),        DF1X(10,5,6),DF2X(10,5,6),
     1DF1D(10,5,7),DF2D(10,5,7),             DYBX(2,5,6),DYBD(2,5,7)
      COMMON/NINE/DBBX(5,6),DBBD(5,7)
      IF(MT.EQ.1) CALL IDENTV
      IF(MT-1)900,1,1
    1 IF(I1.EQ.0) GO TO 2
      IF(MT-I1)100,100,2
    2 IF(I1.EQ.NJ) GO TO 3
      IF(MT-I2)200,200,3
    3 IF(I2.EQ.NJJ) GO TO 1000
      IF(MT-I3)300,300,1300
C
C ----- CONSTRAINTS ON SIDE ONE ALLOCATIONS TO SIDE TWO DEFENSES ------
C
  100 J=MT
      SUM=0.
      DO 110 I=1,NII
  110 SUM = SUM + XX(I,J)
      IF(J.EQ.1) GO TO 150
      IF(ND2.NE.2) GO TO 130
      DO 120 I=1,NII
  120 SUM = SUM + U(I,J+1) + U(I,J+2)
      GO TO 190
  130 DO 140 I=1,NII
  140 SUM = SUM + U(I,J+ND1-1)
      GO TO 190
  150 DO 160 I=1,NII
      DO 161 K=1,ND1
  161 SUM = SUM + U(I,K)
      GO TO 190
  190 VAL = EM(J) - SUM
      GO TO 1300
C
C ----- CONSTRAINTS ON SIDE ONE ALLOCATIONS TO SIDE TWO CV + CF TARGETS
C
  200 J=MT
      SUM=0.
      DO 210 I=1,NII
```

```
  21? SUM=SUM+XX(I,J)
      VAL=EM(J)-SUM
      GO TO 1?0?
C
C ----- CONSTRAINTS ON SIDE ONE ALLOCATIONS TO SIDE TWO CV ONLY TARGETS
C
  3?? J=MT
      SUM = ?.
      DO 31? I=NI1,NII
  31? SUM=SUM+XX(I,J)
      VAL=EM(J)-SUM
      GO TO 1??(
C
C ----- OBJECTIVE FUNCTION   (K1 BETABAR  - K2 BETA) ---------
C
  9?? CALL FRACTS
      VAL = PREFER*BETB-PREBET* BET
 1??? RETURN
      END
```

```
      GO TO 1000
C
C ----- CONSTRAINTS ON SIDE ONE ALLOCATIONS TO SIDE TWO CV + CF TARGETS
C
  200 J=MT
      DO 210 I=1,NII
      N=(J-1)*NII+I
  210 DEL(N) = -1.
      GO TO 1000
C
C ----- CONSTRAINTS ON SIDE ONE ALLOCATIONS TO SIDE TWO CV ONLY TARGETS
C
  300 J=MT-I2
      DO 310 I=1,NI2
      L=NIIJ+(J-1)*NI2+I
  310 DEL(L)=-1.
      GO TO 1000
C
C ----- OBJECTIVE FUNCTION   (K1 BETABAR  - K2 BETA) ---------
C
  900 CALL IDENTV
      CALL FRACTS
      WRITE(6,442)BET,BETB
      CALL DERB
      CALL DERBB
  442 FORMAT( /10X,4HBET=,E11.4,8H   BETB=,E11.4)
      IF(NU3.NE.1) GO TO 409
      WRITE(6,438)
  438 FORMAT( 30X,11HALLOCATIONS)
      DO 401 I=1,NI
  401 WRITE(6,437)( XX(I,J),J=1,NJ)
      DO 402 I=NI1,NII
  402 WRITE(6,437)( XX(I,J),J=1,NJJ)
      IF(ND.LE.0) GO TO 409
      DO 403 I=1,NII
  403 WRITE(6,437)(U(I,K),K=1,ND)
  409 DO 410 J=1,NJ
      DO 410 I=1,NI
      N=(J-1)*NII+I
  410 DEL(N) = PREFER * OBBX(I,J)
      DO 430 I=1,NI2
      DO 420 J=1,NJ
      N=(J-1)*NII+I+NI
  420 DEL(N) =-PREBET * OBX(I,J)
      DO 430 J=1,NJ2
      N=NIIJ+(J-1)*NI2+I
  430 DEL(N) =-PREBET * OBX(I,NJ+J)
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.0) GO TO 1000
      DO 450 K=1,ND
      DO 440 I=1,NI
      N= IEX + (I-1) * ND + K
  440 DEL(N) = PREFER * OBBD(I,K) * B1(I,K) * D(I,K)
      DO 450 I=NI1,NII
      N=IEX + (I-1) * ND + K
  450 DEL(N) =-PREBET* OBD(I-NI,K) * B1(I,K) * D(I,K)
```

```
      SUBROUTINE GRAD1(MT)
C
C ---- THIS SUBROUTINE CALCULATES THE GRADIENT VECTOR OF THE CONSTRAINTS
C ----- AND OBJECTIVE FUNCTION -----
C
      COMMON/SHARE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
      COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IED,IEN
     1,IEU,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NOOFFS,NA,NU1,NU2,NU3
     2,IP1,ND1,NU4,NU5,NU6,NU7,NU8,ND1,ND2
      COMMON/TWO/AA(6),AAB(2),FPOP(6),FPOPB(2),DL(9,7),ENL(10),RB(10),
     1EKB(10),TITLE2(10),P(15,7) ,AB(10,15),B(2,10),DB(2,10),EM(15),
     2E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),LU(15)
      COMMON/THREE/PREFER,PREFIN,PREINC,PREBET,B1(9,5),RD(5)
      COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
      COMMON/FIVE/XX(9,15),D(9,7),EN(10),Q(9,5),U(9,7)
      COMMON/SIX/Z(9,7) ,ZB(2,10),F(9,15),S(10),FB(2,10),EFTA(6),Y(6),
     1BETAB(2),YB(2),BETB,BET
      COMMON/SEVEN/DFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DBX(6,15),
     1DYD(6,7),DBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
      COMMON/EIGHT/DSX(5,6),DSD(5,7),        DF1X(10,5,6),DF2X(10,5,6),
     1DF1D(10,5,7),DF2D(10,5,7),             DYBX(2,5,6),DYBD(2,5,7)
      COMMON/NINE/DBBX(5,6),DBBD(5,7)
      COMMON/ELEVEN/DBXX(90,15),DBXD(90,7),DBDD(30,5)
      COMMON/TWELVE/DSXX(30,6),DSXD(30,7),DSDD(6,5)
      COMMON/FOURTN/DBBXX(30,30),DBBXD(30,35),DBBDD(30,30),D2YB(2)
  437 FORMAT( 10F13.3)
      DO 10 I=1,IED
   10 DEL(I)=0.
      IF(MT-1)90,1,1
    1 IF(I1.EQ.0) GO TO 2
      IF(MT-I1)100,100,2
    2 IF(I1.EQ.NJ) GO TO 3
      IF(MT-I2)200,200,3
    3 IF(I2.EQ.NJJ) GO TO 1000
      IF(MT-I3)300,300,1000
C
C ----- CONSTRAINTS ON SIDE ONE ALLOCATIONS TO SIDE TWO DEFENSES ------
C
  100 J=MT
      DO 110 I=1,NII
      L=(J-1)*NII+I
  110 DEL(L)=-1.
      IF(J.EQ.1) GO TO 150
      IF(ND2.NE.2) GO TO 130
      DO 120 I=1,NII
      DO 120 K=1,ND2
      M= IEX + (I-1) * ND + K + J
  120 DEL(M) = -1.
      GO TO 1000
  130 DO 140 I=1,NII
      M=IEX + (I-1) * ND + J + ND1 - 1
  140 DEL(M) = -1.
      GO TO 1000
  150 DO 160 I=1,NII
      DO 160 K=1,ND1
      M= IEX + (I-1) * ND + K
  160 DEL(M) = -1.
```

```
      GO TC 1000
1000  RETURN
      END
```

```
      SUBROUTINE MATRIX(MT,IK)
C
C ---- THIS SUBROUTINE CALCULATES THE MATRIX OF SECOND PARTIAL DERIV-
C ----- ATIVES OF THE CONSTRAINTS AND OBJECTIVE FUNCTION -----
C
      COMMON/SHARE/ X(100), DEL(100), A(120,100),NV,MC,MN,NP1,NM1
      COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IED,IFN
     1,IFU,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NOFFS,NCOFFS,NN,NU1,NU2,NU3
     2,IB1,ND ,NU4,NU5,NU6,NU7,NU8,ND1,ND2
      COMMON/TWO/AA(6),AAB(2),FPOP(6),FPOPB(2),DL(9,7),ENL(10),RR(10),
     1EKB(10),TITLE2(10),P(15,7) ,AB(10,15),B(2,10),DB(2,10),EM(15),
     2E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),CU(15)
      COMMON/THREE/PREFER,PREFIN,PREINC,PRESET,B1(9,5),RD(5)
      COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
      COMMON/FIVE/XX(9,15),D(9,7),EN(10),Q(9,5),U(9,7)
      COMMON/SIX/Z(9,7) ,ZB(2,10),F(9,15),S(10),FB(2,10),BETA(6),Y(6),
     1BETAB(2),YB(2),BETB,BET
      COMMON/SEVEN/DFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DBX(6,15),
     1DYD(6,7),DBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
      COMMON/EIGHT/DSX(5,6),DSD(5,7),          DF1X(10,5,6),DF2X(10,5,6),
     1DF1D(10,5,7),DF2D(10,5,7),           DYEX(2,5,6),DYBD(2,5,7)
      COMMON/NINE/DBBX(5,6),DBBD(5,7)
      COMMON/ELEVEN/DBXX(90,15),DBXD(90,7),DBDD(30,5)
      COMMON/TWELVE/DSXX(30,6),DSXD(30,7),DSDD(6,5)
      COMMON/FOURTN/DBBXX(30,30),DBBXD(30,35),DBBDD(30,30),D2YB(2)
      IF(MT-1)9[illegible],1,1
    1 IF(I1.EQ.0) GO TO 2
      IF(MT-I1)100,110,2
    2 IF(I1.EQ.NJ) GO TO 3
      IF(MT-I2)200,200,3
    3 IF(I2.EQ.NJJ) GO TO 100[illegible]
      IF(MT-I3)300,300,1000
C
C ----- CONSTRAINTS ON SIDE ONE ALLOCATIONS TO SIDE TWO DEFENSES ------
C
  100 IK=1
      GO TO 1000
C
C ----- CONSTRAINTS ON SIDE ONE ALLOCATIONS TO SIDE TWO CV + CF TARGETS
C
  200 IK=1
      GO TO 1[illegible]
C
C ----- CONSTRAINTS ON SIDE ONE ALLOCATIONS TO SIDE TWO CV ONLY TARGETS
C
  300 IK=1
      GO TO 1000
C
C ----- OBJECTIVE FUNCTION   (K1 BETABAR - K2 BETA) ---------
C
  900 CALL IDENTV
      CALL FRACTS
      CALL DERB
      CALL DERBB
      CALL DER2B
      CALL DER2S
      CALL DER2BB
```

```
      IF(PREFER.EQ.0) GO TO 915
      DO 917 JJ=1,NJ
      DO 917 I=1,NI
      NN2=(JJ-1)*NI+I
      LROW=(JJ-1)*NII+I
      DO 917 J=JJ,NJ
      DO 917 K=I,NI
      M=(J-1) * NI + K
      LCOL=(J-1)*NII+K
  917 A(LROW,LCOL)= PREFER *DBBXX(NN2,M)
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.0) GO TO 910
      DO 916 II=1,NI
      DO 916 K =1,ND
      NN3=(II-1)*ND + K
      LCOL = IEX + NN3
  916 A(LROW,LCOL) = PREFER * DBBXD(NN2,NN3) *B1(II,K) * C(II,K)
  910 CONTINUE
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.0) GO TO 915
      DO 912 I=1,NI
      DO 912 J=1,ND
      NN2 = (I-1) * ND + J
      LROW = IEX + NN2
      DO 912 K=I,NI
      DO 912 KR=J,ND
      NN3 = (K-1) * ND + KR
      LCOL = IEX + NN3
      TERM = 0.
      IF(I.EQ.K.AND.J.EQ.KR) TERM = DBBD(I,J)*B1(I,J)**2*C(I,J)
C
C --- THESE ARE SECOND PARTIAL U CROSS U DERIVATIVES WHICH DID NOT
C --- APPEAR IN RAC-CR-47
C
  912 A(LROW,LCOL) = PREFER*(DBBDD(NN2,NN3)*D(I,J)*D(K,KR)*B1(I,J)*B1(K,
     1KR) + TERM)
  915 IF(PREBET.EQ.0) GO TO 100
      DO 925 JJ=1,NJ
      DO 925 I=1,NI2
      LROW=(JJ-1)*NII+NI+I
      NN2=(JJ-1)*NI2+I
      DO 917 J=JJ,NJ
      LCOL=(J-1)*NII + NI +I
  917 A(LROW,LCOL) = - PREBET * DBXX(NN2,J)
      DO 919 J=1,NJ2
      LCOL = NIIJ + (J-1) * NI2 + I
  919 A(LROW,LCOL) = - PREBET * DBXX(NN2,NJ+J)
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.0) GO TO 925
      DO 920 K=1,ND
      LCOL = IEX +(NI+I-1) * ND + K
  920 A(LROW,LCOL) = -PREBET * DBXD(NN2,K)*B1(NI+I,K)*C(NI+I,K)
```

```
  925 CONTINUE
      DO 93[illegible] JJ=1,NJ2
      DO 93[illegible] I=1,NI2
      LROW=NIIJ+(JJ-1)*NI2+I
      NN2=(JJ-1)*NI2+I+NJ
      DO 926 J=JJ,NJ2
      LCOL=NIIJ+(J-1)*NI2+I
  926 A(LROW,LCOL)=-PREBET * DBXX(NN2,NJ+J)
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.0) GO TO 935
      DO 928 K=1,ND
      LCOL = IEX + (NI+I-1) * ND + K
  928 A(LROW,LCOL) = -PREBET * DBXD(NN2,K) *B1(NI+I,K)*D(NI+I,K)
  93[illegible] CONTINUE
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.0) GO TO 10[illegible]
      DO 94[illegible] I=NI1,NII
      DO 94[illegible] KK=1,ND
      LROW = IEX + (I-1) * ND + KK
      NN2 = ( I - 1 ) * ND + KK - ND * NI
      DO 93[illegible] K=KK,ND
      LCOL = IEX + (I-1) * ND + K
      TERM = 0.
      IF(K.EQ.KK) TERM = DBD(I-NI,K) * B1(I,K)**2 * D(I,K)
C
C --- THESE ARE SECOND PARTIAL U CROSS U DERIVATIVES WHICH DID NOT
C --- APPEAR IN RAC-CP-43
C
  935 A(LROW,LCOL) = - PREBET * (DBDD(NN2,K)*D(I,K)*D(I,KK)*B1(I,K)*B1(I
     1,KK) + TERM)
  94[illegible] CONTINUE
 1[illegible] RETURN
      END
```

```
      SUBROUTINE IDENTV
C
C --- THESE COMPUTIONS ARE THE SAME AS THOSE DESCRIBED IN RAC-CR-43 PART
C --- IV-B.     WITH EXCEPTIONS AS NOTED IN THE COMMENT CARDS -------
C
      COMMON/SHARE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
      COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IED,IEN
     1,IEU,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NCOFFS,NN,NU1,NU2,NU3
     2,IB1,ND ,NU4,NU5,NU6,NU7,NU8,ND1,ND2
      COMMON/TWO/AA(6),AA3(2),FPOF(6),FPOFB(2),DL(9,7),ENL(10),RB(10),
     1EKR(10),TITLE2(10) ,C(15,7) ,AB(10,15),B(2,10),DB(2,10),EM(15),
     2E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),LU(15)
      COMMON/THREE/PREFER,PREFIN,PREINC,PRERET,B1(9,5),RD(5)
      COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
      COMMON/FIVE/XX(9,15),D(9,7),EN(10),Q(9,5),U(9,7)
      COMMON/SIX/Z(9,7) ,ZB(2,10),F(9,15),S(10),FB(2,10),BETA(6),Y(6),
     1BETAB(2),YB(2),BETB,BET
      COMMON/SEVEN/DFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DBX(6,15),
     1DYD(6,7),DBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
      COMMON/EIGHT/DSX(5,6),DSD(5,7),        DF1X(10,5,6),DF2X(10,5,6),
     1DF1D(10,5,7),DF2D(10,5,7),             DYBX(2,5,6),DYBD(2,5,7)
      COMMON/NINE/DBBX(5,6),DBBD(5,7)
C **THIS SUBROUTINE IDENTIFIES MODEL VARIABLES WITH SUMT VARIABLES XXX
      DO 1? J=1,NJ
      JJ=(J-1)*NII
      DO 1? I=1,NII
      K=JJ+I
   1? XX(I,J)=X(K)
      DO 2? J=1,NJ2
      JJ = NIIJ+(J-1)*NI2
      DO 2? I=NI1,NII
      K=JJ+I-NI
      L=NJ + J
   2? XX(I,L)=X(K)
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.?) GO TO 6?
      DO 3? I=1,NII
C
C --- ND REPLACES NK IN EQUIVALENT INSTRUCTION OF RAC-CR-43 PART IV-B.
C
      II = (I-1) * ND + IEX
      DO 3? K=1,ND
      L=II+K
   3? U(I,K) = X(L)
   6? RETURN
      END
```

```
      SUBROUTINE FRACTS
C
C --- THESE COMPUTIONS ARE THE SAME AS THOSE DESCRIBED IN RAC-CR-43 PART
C --- IV-B.    WITH EXCEPTIONS AS NOTED IN THE COMMENT CARDS -------
C
      COMMON/SHARE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
      COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IED,IEN
     1,IEU,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NCOFFS,NN,NU1,NU2,NU3
     2,IB1,ND ,NU4,NU5,NU6,NU7,NU8,ND1,ND2
      COMMON/TWO/AA(6),AAB(2),FPOP(6),FPOPB(2),DL(9,7),ENL(10),RB(10),
     1EKB(10),TITLE2(10),P(15,7) ,AB(10,15),B(2,10),DB(2,10),EM(15),
     2E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),LU(15)
      COMMON/THREE/PREFER,PRFFIN,PREINC,PREBET,B1(9,5),RD(5)
      COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
      COMMON/FIVE/XX(9,15),D(9,7),EN(10),Q(9,5),U(9,7)
      COMMON/SIX/Z(9,7) ,ZB(2,10),F(9,15),S(10),FB(2,10),BETA(6),Y(6),
     1BETAB(2),YB(2),BETB,BET
      COMMON/SEVEN/DFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DBX(6,15),
     1DYD(6,7),DBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
      COMMON/EIGHT/DSX(5,6),DSD(5,7),        DF1X(10,5,6),DF2X(10,5,6),
     1DF1D(10,5,7),DF2D(10,5,7),             DYBX(2,5,6),DYBD(2,5,7)
      COMMON/NINE/DBBX(5,6),DBBD(5,7)
C
C** COMPUTE FRACTIONS F,S,AND FBAR ,BETA,BETABAR, ALSO Z ZBAR Y YBAR
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.0) GO TO 7
      DO 5 I=1,NII
C
C --- ND REPLACES NK IN EQUIVALENT INSTRUCTION OF RAC-CR-43 PART IV-B.
C
      DO 5 K=1,NC
    5 D(I,K) = DL(I,K) * EXP(B1(I,K)*U(I,K))
    7 DO 30 J=1,NJ
      DO 30 I=1,NI
      SUM=0.
      DO 20 K=1,NK
      Z(I,K)=0.
      DO 10 L=1,NJ
   10 Z(I,K)= Z(I,K) + XX(I,L)*AN(L,K)
      IF(Z(I,K).LE.0.)Z(I,K)=1.E-100
   20 SUM= SUM+ C(J,K)*D(I,K)/Z(I,K)
      IF(SUM .LE.-140.)SUM =-140.
      IF(SUM .GT.140.)SUM =140.
   30 F(I,J)= EXP(SUM)
      DO 60 I=NI1,NII
      DO 60 J=1,NJJ
      SUM=0.
      DO 50 K=1,NK
      Z(I,K)=0.
      DO 40 L=1,NJJ
   40 Z(I,K)=Z(I,K)+ XX(I,L)*AN(L,K)
      IF(Z(I,K).LE.0.)Z(I,K)=1.E-100
   50 SUM=SUM+C(J,K)*D(I,K)/Z(I,K)
      IF(SUM .LE.-140.)SUM =-140.
      IF(SUM .GT.140.)SUM =140.
   60 F(I,J)=EXP(SUM)
```

```
      DO 10C I=1,NI
      SUM=C.
      DO 9C  J=1,NJ
   9C SUM=SUM+XX(I,J)*F(I,J)*ELNS(I,J)
      SU =SUM/EN(I)
      IF(SUM .LE.-14C.)SUM =-14C.
      IF(SUM .GT.14C.)SUM =14C.
  1C  S(I) = RR(I) * EXP(SUM)
      DO 14C L=1,NL
      DO 14C M=1,NM
      SUM2=C.
      DO 13C N=1,NN
      SUM1=C.
      DO 12C K=1,NM
  12C SUM1=SUM1+S(K)*EN(K)*AR(K,N)
      ZR(L,N)= FFORR(L)* SUM1
      IF(ZR(L,N).LE.C.)ZR(L,N)=1.E-1CC
  13C SUM2=SUM2+CR(M,N)*CR(L,N)/ZR(L,N)
      IF(SUM2.LE.-14C.)SUM2=-14C.
      IF(SUM2.GT.14C.)SUM2=14C.
  14C FR(L,M)=EXP(SUM2)
      RET=C.
      DO 2CC I=1,NI2
      Y(I)=C.
      DO 15C J=1,NJJ
  15C Y(I)=Y(I)+F(NI+I,J)*XX(NI+I,J)*FK(J)
      IF(Y(I).LE.C.)Y(I)=1.E-1CC
      TERM=AA(I)*SQRT(Y(I))
      RETA(I)=1.-(1.+TERM)*EXP(-TERM)
  2CC RET=RET + FFOP(I)*RETA(I)
      RET=C.
      DO 3CC L=1,NL
      YR(L)=C.
      DO 25C M=1,NM
  25C YR(L)=YR(L)+ FR(L,M)*S(M)*EN(M)*FKR(M)
      IF(YR(L).LE.C.)YR(L)=1.E-1CC
      YR(L) = FFORR(L) * YR(L)
      TERM= AAR(L)*SQRT(YR(L))
      RETAR(L)=1.-(1.+TERM)*EXP(-TERM)
  3CC RETR=RETR + FFORR(L)*RETAR(L)
      RETURN
      END
```

```
      SUBROUTINE DERB
C
C --- THESE COMPUTIONS ARE THE SAME AS THOSE DESCRIBED IN RAC-CR-43 PART
C --- IV-B.    WITH EXCEPTIONS AS NOTED IN THE COMMENT CARDS -------
C
      COMMON/SHARE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
      COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IED,IEN
     1,IEU,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NCOEFS,NA,NU1,NU2,NU3
     2,IB1,ND ,NU4,NU5,NU6,NU7,NU8,ND1,ND2
      COMMON/TWO/AA(6),AAB(2),FPOP(6),FPOPB(2),DL(9,7),ENL(10),RB(10),
     1EKB(10),TITLE2(10),P(15,7) ,AB(10,15),B(2,10),DB(2,10),EM(15),
     2E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),LU(15)
      COMMON/THREE/PREFER,PREFIN,PREINC,PREBET,B1(9,5),RD(5)
      COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
      COMMON/FIVE/XX(9,15),D(9,7),EN(10),Q(9,5),L(9,7)
      COMMON/SIX/Z(9,7) ,ZB(2,10),F(9,15),S(10),FB(2,10),BETA(6),Y(6),
     1BETAB(2),YB(2),BETB,BET
      COMMON/SEVEN/DFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DBX(5,15),
     1DYD(6,7),DBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
      COMMON/EIGHT/DSX(5,6),DSD(5,7),        DF1X(10,5,6),DF2X(10,5,6),
     1DF1D(10,5,7),DF2D(10,5,7),             DYBX(2,5,6),DYBD(2,5,7)
      COMMON/NINE/DBBX(5,6),DBBD(5,7)
C** COMPUTES FIRST DERIVATIVES OF BETA, ALSO DERS. OF F  ***
      DO 30 I=1,NI
      DO 30 J=1,NJ
      DO 30 L=1,NJ
      SUM=0.
      DO 20 K=1,NK
   20 SUM=SUM+C(J,K)*D(I,K)*AN(L,K)/Z(I,K)**2
   30 DFX(I,J,L)=-SUM*F(I,J)
      DO 60 I=NI1,NII
      DO 60 J=1,NJJ
      DO 60 L=1,NJJ
      SUM=0.
      DO 50 K=1,NK
   50 SUM=SUM+C(J,K)*D(I,K)*AN(L,K)/Z(I,K)**2
   60 DFX(I,J,L)=-SUM*F(I,J)
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.0) GO TO 85
      DO 79 I=1,NI
C
C --- ND REPLACES NK IN EQUIVALENT INSTRUCTION OF RAC-CR-43 PART IV-B.
C
      DO 76 J=1,NJ
      DO 76 K=1,ND
   76 DFD(I,J,K)=F(I,J)*C(J,K)/Z(I,K)
      DO 80 I=NI1,NII
      DO 80 J=1,NJJ
      DO 80 K=1,ND
   80 DFD(I,J,K)=F(I,J)*C(J,K)/Z(I,K)
   85 DO 90 I=1,NI2
   90 BETP(I)=AA(I)**2*EXP(-AA(I)*SQRT(Y(I)))/2.
      DO 120 I=1,NI2
      DO 120 J=1,NJJ
      SUM=0.
```

```
      DO 110 K=1,NJJ
  110 SUM=SUM+XX(NI+I,K)*DFX(NI+I,K,J) * EK(K)
      DYX(I,J)=SUM +F(NI+I,J)*EK(J)
  120 DBX(I,J)=FFOP(I)*BETP(I)*DYX(I,J)
C
C --- IF NC ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.0) GO TO 150
C
C --- ND REPLACES NK IN EQUIVALENT INSTRUCTION OF RAC-CR-43 PART IV-B.
C
      DO 140 K=1,ND
      DO 140 I=1,NI2
      SUM=0.
      DO 130 J=1,NJJ
  130 SUM=SUM+XX(NI+I,J)*DFD(NI+I,J,K) * EK(J)
      DYD(I,K)=SUM
  140 DBD(I,K)=FFOP(I)*BETP(I)*DYD(I,K)
  150 RETURN
      END
```

```
      SUBROUTINE DFRBB
C
C --- THESE COMPUTIONS ARE THE SAME AS THOSE DESCRIBED IN RAC-CR-43 PART
C --- IV-B.    WITH EXCEPTIONS AS NOTED IN THE COMMENT CARDS -------
C
      COMMON/SHARE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
      COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IED,IEN
     1,IFU,IEX1,IEXEN,T1,I2,I3,I4,I5,I6,I7,NDEFS,NCCFFS,NA,NU1,NU2,NU3
     2,IB1,ND ,NU4,NU5,NU6,NU7,NU8,ND1,ND2
      COMMON/TWO/AA(6),AAB(2),FPOP(6),FPOPB(2),DL(9,7),ENL(10),RB(10),
     1EKB(10),TITLE2(10),P(15,7) ,AB(10,15),B(2,10),DB(2,10),FM(15),
     2F(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),CU(15)
      COMMON/THREE/PREFER,PREFIN,PREINC,PREBET,B1(9,5),RD(5)
      COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
      COMMON/FIVE/XX(9,15),D(9,7),EN(10),Q(9,5),L(9,7)
      COMMON/SIX/Z(9,7) ,ZB(2,10),F(9,15),S(10),FB(2,10),EFTA(6),Y(6),
     1BETAB(2),YB(2),BETB,BET
      COMMON/SEVEN/DFX(9,15,15),DFD(9,15,7),BETF(6),DYX(6,15),DBX(6,15),
     1DYD(6,7),DBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
      COMMON/EIGHT/DSX(5,6),DSD(5,7),        DF1X(10,5,6),DF2X(10,5,6),
     1DF1D(10,5,7),DF2D(10,5,7),             DYBX(2,5,6),DYBD(2,5,7)
      COMMON/NINE/DBBX(5,6),DBBD(5,7)
      DO 80 M=1,NI
      DO 20 J=1,NJ
      SUM=0.
      DO 10 L=1,NJ
   10 SUM=SUM+XX(M,L)*DFX(M,L,J)*ELNS(M,L)
      SUM=SUM+F(M,J)*ELNS(M,J)
   20 DSX(M,J)=S(M)*SUM/EN(M)
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.0) GO TO 80
C
C --- ND REPLACES NK IN EQUIVALENT INSTRUCTION OF RAC-CR-43 PART IV-B.
C
      DO 40 K=1,ND
      SUM=0.
      DO 30 L=1,NJ
   30 SUM=SUM+XX(M,L)*DFD(M,L,K)*ELNS(M,L)
   40 DSD(M,K)=S(M)*SUM/EN(M)
   80 CONTINUE
      DO 120 L=1,NL
      DO 120 M=1,NM
      DO 120 I=1,NI
      DO 120 J=1,NJ
      SUM=0.
      DO 110 N=1,NN
  110 SUM=SUM+CB(M,N)*CB(L,N)*AB(I,N)/ZB(L,N)**2
      SUM=-FPOPB(L)*FB(L,M)*DSX(I,J)*EN(I)*SUM
      GO TO(111,112),L
  111 DF1X(M,I,J)=SUM
      GO TO 120
  112 DF2X(M,I,J)=SUM
  120 CONTINUE
      IF(ND.LE.0) GO TO 195
      DO 140 L=1,NL
```

```
      DO 140 M=1,NM
      DO 140 I=1,NI
C
C --- ND REPLACES NK IN EQUIVALENT INSTRUCTION OF PAC-CR-43 PART IV-B.
C
      DO 140 K=1,ND
      SUM=0.
      DO 130 N=1,NN
  130 SUM=SUM+CB(M,N)*CB(L,N)*AB(I,N)/ZB(L,N)**2
      SUM=-FPOPP(L)*FB(L,M)*DSO(I,K)*EN(I) * SUM
      GO TO(131,132),L
  131 DF1D(M,I,K)=SUM
      GO TO 140
  132 DF2D(M,I,K)=SUM
  140 CONTINUE
  195 DO 230 L=1,NL
      DO 230 I=1,NI
      DO 230 J=1,NJ
      SUM=0.
      DO 220 M=1,NM
      GO TO (211,212),L
  211 TEMP=DF1X(M,I,J)
      GO TO 220
  212 TEMP=DF2X(M,I,J)
  220 SUM=SUM+TEMP*S(M)*EN(M)*EKB(M)
      SUM=SUM+FB(L,I)*DSX(I,J)*EN(I)*EKB(I)
  230 DYBX(L,I,J)=FPOPB(L)*SUM
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.0) GO TO 295
      DO 260 L=1,NL
      DO 260 I=1,NI
      DO 260 K=1,ND
      SUM=0.
      DO 250 M=1,NM
      GO TO (241,242),L
  241 TEMP=DF1D(M,I,K)
      GO TO 250
  242 TEMP=DF2D(M,I,K)
  250 SUM=SUM+TEMP*S(M)*EN(M)*EKB(M)
      SUM=SUM+FB(L,I)*DSO(I,K)*EN(I)*EKB(I)
  260 DYBD(L,I,K)=FPOPP(L)*SUM
  295 DO 300 L=1,NL
  300 BETBP(L)=AAB(L)**2*EXP(-AAB(L)*SQRT(YB(L)))/2.
      DO 350 I=1,NI
      DO 350 J=1,NJ
      SUM=0.
      DO 340 L=1,NL
  340 SUM=SUM+FPOPB(L)*BETBP(L)*DYBX(L,I,J)
  350 DBBX(I,J)=SUM
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.0) GO TO 1000
      DO 370 I=1,NI
      DO 370 K=1,ND
      SUM=0.
```

```
      DO 360 L=1,NL
  360 SUM=SUM+FPOPB(L)*BETBP(L)*DYBD(L,I,K)
  370 DBBD(I,K)=SUM
 1000 RETURN
      END
```

```
      SUBROUTINE DER2B
C
C --- THESE COMPUTIONS ARE THE SAME AS THOSE DESCRIBED IN RAC-CR-43 PART
C --- IV-B.    WITH EXCEPTIONS AS NOTED IN THE COMMENT CARDS -------
C
      COMMON/SHAPE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
      COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IED,IEN
     1,IEU,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NCOFFS,NA,NU1,NU2,NU3
     2,I81,ND ,NU4,NU5,NU6,NU7,NU8,ND1,ND2
      COMMON/TWO/AA(6),AAB(2),FPOF(6),FPOPB(2),DL(9,7),ENL(10),RB(10),
     1EKB(10),TITLE2(10),F(15,7) ,AB(10,15),B(2,10),DB(2,10),EM(15),
     2E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),CU(15)
      COMMON/THREE/PREFER,PREFIN,PREINC,PREBET,B1(9,5),RD(5)
      COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
      COMMON/FIVE/XX(9,15),D(9,7),EN(10),G(9,5),U(9,7)
      COMMON/SIX/Z(9,7) ,ZB(2,10),F(9,15),S(10),FB(2,10),BETA(6),Y(6),
     1BETAB(2),YB(2),BETB,BET
      COMMON/SEVEN/DFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DBX(6,15),
     1DYD(6,7),DBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
      COMMON/EIGHT/DSX(5,6),DSD(5,7),        DF1X(10,5,6),DF2X(10,5,6),
     1DF1D(10,5,7),DF2D(10,5,7),             DYBX(2,5,6),DYBD(2,5,7)
      COMMON/NINE/DBBX(5,6),DBBD(5,7)
      COMMON/ELEVEN/DBXX(90,15),DBXD(90,7),DBDD(30,5)
      COMMON/TWELVE/DSXX(30,6),DSXD(30,7),DSDD(6,5)
      COMMON/FOURTN/DBBXX(30,30),DBBXD(30,35),DBBDD(30,30),D2YB(2)
      DO 5 I=1,NI2
      TERM = SQRT(Y(I))
      IF(TERM)4,3,4
    3 BETPP(I)=-1.E+10
      GO TO 5
    4 BETPP(I)=-AA(I)**3*EXP(-AA(I)*TERM) / (4.*TERM)
    5 CONTINUE
      DO 70 I=NI1,NII
      DO 60 J=1,NJJ
      NN2 = ( J - 1 ) *NI2 + I - NI
      DO 30 KR=1,NJJ
      SUM=0.
      DO 20 K=1,NJ
      NN1=(K-1)*NII+I
   20 SUM=SUM+DFXX(NN1,J,KR)* XX(I,K) * EK(K)
      IF(NJ.EQ.NJJ) GO TO 26
      DO 25 K=NJ1,NJJ
      NN1=NIIJ+(K-1-NJ)*NI2+I-NI
   25 SUM=SUM+DFXX(NN1,J,KR)*XX(I,K)*EK(K)
   26 D2YXX=SUM+DFX(I,KR,J)*EK(KR)+DFX(I,J,KR)*EK(J)
      III=I-NI
   30 DBXX(NN2,KR)=FPOP(III)*(BETPP(III)*DYX(III,J)*DYX(III,KR)+BETP(III
     1)*D2YXX)
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.0) GO TO 60
C
C --- ND REPLACES NK IN EQUIVALENT INSTRUCTION OF RAC-CR-43 PART IV-B.
C
      DO 50 KR = 1,ND
      SUM=0.
```

```
      DO 40 K=1,NJ
      NN1=(K-1)*NII+I
   40 SUM=SUM+DFXD(NN1,J,KR)*XX(I,K)*EK(K)
      IF(NJ.EQ.NJJ) GO TO 46
      DO 45 K=NJ1,NJJ
      NN1=NIIJ+(K-1-NJ)*NI2+I-NI
   45 SUM=SUM+DFXD(NN1,J,KR)*XX(I,K)*EK(K)
   46 D2YXD=SUM+DFD(I,J,KR)*EK(J)
      K=I-NI
   50 DBXD(NN2,KR)=FPOP(K)*(BETPP(K)*DYX(K,J)*DYD(K,KR)+BETP(K)*D2YXD)
   60 CONTINUE
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.0) GO TO 70
      DO 56 K=1,ND
C
C --- THESE ARE SECOND PARTIAL D CROSS D DERIVATIVES WHICH DID NOT
C --- APPEAR IN RAC-CR-43 BUT ARE DESCRIBED IN THE PRESENT REPORT -------
C
      NN2=(I-1) * NC + K  - ND * NI
      DO 56 KR=1,ND
      SUM=0.
      DO 54 J=1,NJ
      NN1 = (J - 1) * NII + I
   54 SUM=SUM + DFDC(NN1,K,KR) * XX(I,J) * EK(J)
      IF(NJ.EQ.NJJ) GO TO 53
      DO 52 J=NJ1,NJJ
      NN1 = NIIJ + (J-1-NJ) * NI2 + I - NI
   52 SUM=SUM + DFDC(NN1,K,KR) * XX(I,J) * EK(J)
   53 D2YDD=SUM
      III= I - NI
   56 DBDD(NN2,KR) = FPOP(III)*(BETPP(III)*DYD(III,K)*DYD(III,KR)+BETP(I
     1II)*D2YDD)
   70 CONTINUE
      RETURN
      END
```

```
      SUBRCUTINE DER2S
C
C --- THESE COMPUTIONS ARE THE SAME AS THOSE DESCRIBED IN RAC-CR-43 PART
C --- IV-B.    WITH EXCEPTIONS AS NOTED IN THE COMMENT CARDS -------
C
      COMMON/SHARE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
      COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IED,IEN
     1,IEU,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NCOFFS,NN,NU1,NU2,NU3
     2,IB1,ND ,NU4,NU5,NU6,NU7,NU8,NC1,ND2
      COMMON/TWO/AA(6),AAB(2),FPOP(6),FPOPB(2),DL(9,7),ENL(10),RB(10),
     1EKB(10),TITLE2(10),P(15,7) ,AB(10,15),B(2,10),DE(2,10),EM(15),
     2E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),LU(15)
      COMMON/THREE/PREFER,PREFIN,PREINC,PPERET,B1(9,5),RD(5)
      COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
      COMMON/FIVE/XX(9,15),D(9,7),EN(10),G(9,5),U(9,7)
      COMMON/SIX/Z(9,7) ,ZB(2,10),F(9,15),S(10),FB(2,10),EETA(6),Y(6),
     1BETAB(2),YB(2),BETB,BET
      COMMON/SEVEN/DFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DBX(6,15),
     1DYD(6,7),DBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
      COMMON/EIGHT/DSX(5,6),DSD(5,7),        DF1X(10,5,6),DF2X(10,5,6),
     1DF1D(10,5,7),DF2D(10,5,7),             DYBX(2,5,6),DYBD(2,5,7)
      COMMON/NINE/DBBX(5,6),DBBD(5,7)
      COMMON/ELEVEN/DBXX(90,15),DBXD(90,7),DBDD(30,5)
      COMMON/TWELVE/DSXX(30,6),DSXD(30,7),DSDD(6,5)
      COMMON/FOURTN/DBBXX(30,30),DBBXD(30,35),DBBDD(30,30),D2YB(2)
      DO 40 M=1,NI
      DO 40 K=1,NJ
      NN2=(K-1)*NI+M
      DO 40 L=1,NJ
      IF(S(M)-0.)20,20,25
   20 DSXX(NN2,L)=0.
      GO TO 40
   25 SUM=0.
      DO 30 J=1,NJ
      NN1=(J-1)*NII+M
   30 SUM=SUM+XX(M,J)*DFXX(NN1,K,L)*ELNS(M,J)
      DSXX(NN2,L)=DSX(M,L)*DSX(M,K)/S(M)+S(M)*(DFX(M,K,L)*ELNS(M,K)+
     1DFX(M,L,K)*ELNS(M,L)+SUM)/EN(M)
   40 CONTINUE
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.0) GO TO 100
      DO 90 M=1,NI
      DO 70 K=1,NJ
C
C --- ND REPLACES NK IN EQUIVALENT INSTRUCTION OF RAC-CR-43 PART IV-B.
C
      NN2=(K-1)*NI+M
      DO 70 L=1,ND
      IF(S(M)-0.)45,45,50
   45 DSXD(NN2,L) = 0.
      GO TO 70
   50 SUM=0.
      DO 60 J=1,NJ
      NN1=(J-1)*NII+M
   60 SUM=SUM+XX(M,J)*DFXD(NN1,K,L)*ELNS(M,J)
```

```
      DSXD(NN2,L)=DSD(M,L)*DSX(M,K)/S(M)+S(M)*(DFD(M,K,L)*ELNS(M,K)+
     1SUM)/EN(M)
   70 CONTINUE
C
C --- THESE ARE SECOND PARTIAL U CROSS U DERIVATIVES WHICH DID NOT
C --- APPEAR IN RAC-CR-43 BUT ARE DESCRIBED IN THE PRESENT REPORT ------
C
      DO 80 K=1,ND
      NN2 = (M-1) * ND + K
      DO 80 L=1,ND
      IF(S(M)-0.)72,72,75
   72 DSDD(NN2,L) = 0.
      GO TO 80
   75 SUM = 0.
      DO 78 J=1,NJ
      NN1=(J-1) * NII + M
   78 SUM = SUM + XX(M,J) * DFDD(NN1,K,L) * ELNS(M,J)
      DSDD(NN2,L) = DSD(M,L) * DSD(M,K) / S(M) + S(M) * SUM / EN(M)
   80 CONTINUE
   90 CONTINUE
  100 RETURN
      END
```

```
      SUBROUTINE DER2BB
C
C --- THESE COMPUTIONS ARE THE SAME AS THOSE DESCRIBED IN RAC-CR-43 PART
C --- IV-B.    WITH EXCEPTICNS AS NOTED IN THE COMMENT CARDS -------
C
      COMMON/SHARE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
      COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IEO,IEN
     1,IEU,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NCOFFS,NA,NU1,NU2,NU3
     2,I81,ND ,NU4,NU5,NU6,NU7,NU8,ND1,ND2
      COMMON/TWO/AA(6),AAB(2),FPOP(6),FPOPB(2),DL(9,7),ENL(10),RB(10),
     1EKB(10),TITLE2(10),P(15,7) ,AB(10,15),B(2,10),DB(2,10),EM(15),
     2E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),LU(15)
      COMMON/THREE/PREFER,PREFIN,PREINC,PREBET,B1(9,5),RD(5)
      COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
      COMMON/FIVE/XX(9,15),D(9,7),EN(10),D(9,5),U(9,7)
      COMMON/SIX/Z(9,7) ,ZB(2,10),F(9,15),S(10),FB(2,10),BETA(6),Y(6),
     1BETAB(2),YB(2),BETB,BET
      COMMON/SEVEN/DFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DEX(6,15),
     1DYD(6,7),DBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
      COMMON/EIGHT/DSX(5,6),DSD(5,7),        DF1X(10,5,6),DF2X(10,5,6),
     1DF1D(10,5,7),DF2D(10,5,7),             DYBX(2,5,6),DYBD(2,5,7)
      COMMON/NINE/DBBX(5,6),DBBD(5,7)
      COMMON/ELEVEN/DBXX(90,15),DBXD(90,7),DBDD(30,5)
      COMMON/TWELVE/DSXX(30,6),DSXD(30,7),DSDD(6,5)
      COMMON/FOURTN/DBBXX(30,30),DBBXD(30,35),DBBDD(30,30),D2YB(2)
      DO 5 L = 1,NL
      TERM=SQRT(YB(L))
      IF(TERM-1.)4,3,4
    3 BETBPP(L)=-1.E+10
      GO TO 5
    4 BETBPP(L) = -AAB(L)**3*EXP(-AAB(L)*TERM)/(4.*TERM)
    5 CONTINUE
      DO 65 I=1,NI
      DO 65 J=1,NJ
      NN2=(J-1)*NI +I
      DO 62 K=1,NI
      DO 3? KR=1,NJ
      NN3 = (KR - 1) * NI + K
      DO 2? L=1,NL
      SUM=0.
      DO 1? M=1,NM
      NN1=(L-1)*NM+M
   11 SUM=SUM+DFBXX(NN1,NN2,NN3)*S(M)*EN(M)*EKB(M)
      GO TO(12,14),L
   12 TERM1L=DF1X(K,I,J)
      TERM2L=DF1X(I,K,KR)
      GO TO 15
   14 TERM1L=DF2X(K,I,J)
      TERM2L=DF2X(I,K,KR)
   15 TERM2=TERM1L*DSX(K,KR)*EN(K)*EKB(K)
      TERM3=TERM2L*DSX(I,J)*EN(I)*EKB(I)
      TERM4=0.
      IF(I.EQ.K)TERM4=FB(L,I)*EN(I)*EKB(I)*DSXX(NN2,KR)
   2? D2YB(L)=FPOPB(L)*(SUM+TERM2+TERM3+TERM4)
      SUM=0.
      DO 25 L=1,NL
   25 SUM=SUM+FPOPB(L)*(BETBPP(L)*DYBX(L,I,J)*DYBX(L,K,KR)+BETBP(L)*
```

```
     1D2YB(L))
  3( D8BXX(NN2,NN3)=SUM
     IF(ND.LE.( ) GC TO 62
     DO 6( KR=1,ND
     NN3 = (K-1) * ND + KR
     DO 5( L=1,NL
     SUM=(.
     DO 4( M=1,NM
     NN1=(L-1)*NM+M
  4( SUM=SUM+DFBXD(NN1,NN2,NN3)*S(M)*EN(M)*EKB(M)
     GO TO(42,44),L
  42 TERM1L=DF1X(K,I,J)
     TERM2L=DF1D(I,K,KR)
     GO TO 45
  44 TERM1L=DF2X(K,I,J)
     TERM2L=DF2D(I,K,KR)
  45 TERM2=TERM1L *DSD(K,KR)*EN(K)*EKB(K)
     TERM3=TERM2L *DSX(I,J)*EN(I)*EKB(I)
     TERM4=(.
     IF(I.EQ.K)TERM4=FB(L,I)*EN(I)*EKB(I)*DSXD(NN2,KR)
  5( D2YB(L)=FPOPB(L)*(SUM+TERM2+TERM3+TERM4)
     SUM=(.
     DO 55 L=1,NL
  55 SUM=SUM+FPOPB(L)*(BETBPP(L)*DYBX(L,I,J)*DYBD(L,K,KR)+BETBP(L)*
    1D2YB(L))
  6( D8BXD(NN2,NN3)=SUM
  62 CONTINUE
  65 CONTINUE
C
C --- IF NC ATTACK CN DEFENSES BYPASS THIS SECTION --------
C
     IF(ND.LE.() GO TO 1D(
C
C --- THESE ARE SECCND PARTIAL D CROSS D DERIVATIVES WHICH DID NOT
C --- APPEAR IN RAC-CR-43
C
     DO 9( I=1,NI
     DO 9( J=1,ND
     NN2 = (I-1) * ND + J
     DO 9( K=1,NI
     DO 9( KR = 1,ND
     NN3 = (K-1) * ND + KR
     DO 8( L=1,NL
     SUM=(.
     DO 7( M=1,NM
     NN1=(L-1)*NM+M
  7( SUM=SUM+DFBDD(NN1,NN2,NN3)*S(M)*EN(M)*EKB(M)
     GO TO(72,74),L
  72 TERM1L=DF1D(K,I,J)
     TERM2L = DF1D(I,K,KR)
     GO TO 75
  74 TERM1L=DF2D(K,I,J)
     TERM2L=DF2D(I,K,KR)
  75 TERM2=TERM1L *DSD(K,KR)*EN(K)*EKB(K)
     TERM3=TERM2L *DSD(I,J)*EN(I)*EKB(I)
     TERM4=(.
     IF(I.EQ.K)TERM4=FB(L,I)*EN(I)*EKB(I)*DSDD(NN2,KR)
  8( D2YB(L)=FPOPB(L)*(SUM+TERM2+TERM3+TERM4)
```

```
      SUM=0.
      DO 85 L=1,NL
   85 SUM=SUM+FFCFB(L)*(BETBPP(L)*DYBD(L,I,J)*DYBD(L,K,KR)+BETBF(L)*
     1D2YB(L))
   90 DBBDD(NN2,NN3)=SUM
  100 RETURN
      END
```

```
      FUNCTION DFXD(NN1,L,KS)
C
C --- THESE COMPUTIONS ARE THE SAME AS THOSE DESCRIBED IN RAC-CR-43 PART
C --- IV-B.    WITH EXCEPTIONS AS NOTED IN THE COMMENT CARDS -------
C
      COMMON/SHARE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
      COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IED,IEN
     1,IEU,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NCOFFS,NN,NU1,NU2,NU3
     2,IB1,ND ,NU4,NU5,NU6,NU7,NU8,ND1,ND2
      COMMON/TWO/AA(6),AAB(2),FFOP(6),FFOPB(2),DL(9,7),ENL(10),RR(10),
     1EKR(10),TITLE2(10),P(15,7) ,AB(10,15),B(2,10),DB(2,10),EM(15),
     2E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),LU(15)
      COMMON/THREE/PREFER,PREFIN,PREINC,PRESET,B1(9,5),RD(5)
      COMMON/FOUR/ C(15,7),CB(10,15),FLNS(5,6)
      COMMON/FIVE/XX(9,15),D(9,7),EN(10),G(9,5),U(9,7)
      COMMON/SIX/Z(9,7) ,ZB(2,10),F(9,15),S(10),FB(2,10),BETA(6),Y(6),
     1BETAB(2),YB(2),BETB,BET
      COMMON/SEVEN/DFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DBX(6,15),
     1DYD(6,7),DBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
      COMMON/EIGHT/DSX(5,6),DSD(5,7),          DF1X(10,5,6),DF2X(10,5,6),
     1DF1D(10,5,7),DF2D(10,5,7),               DYBX(2,5,6),DYBD(2,5,7)
      COMMON/NINE/DBBX(5,6),DBBD(5,7)
      COMMON/ELEVEN/DBXX(90,15),DBXD(90,7),DBDD(30,5)
      COMMON/TWELVE/DSXX(30,6),DSXD(30,7),DSDD(6,5)
      COMMON/FOURTN/DBBXX(30,30),DBBXD(30,35),DBBDD(30,30),D2YB(2)
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.0) GO TO 100
      IF(NN1-NIIJ)8,8,7
    7 J=NJ + (NN1-NIIJ-1)/NI2 + 1
      I=NI + (NN1-NIIJ) - (J-NJ-1)*NI2
      GO TO 9
    8 J=(NN1-1)/NII+1
      I=NN1-(J-1)*NII
    9 SUM=0.
      DO 70 K=1,NK
   70 SUM=SUM+C(J,K)*D(I,K)*AN(L,K)/Z(I,K)**2
      DFXD=-DFD(I,J,KS)*SUM-F(I,J)*C(J,KS)*AN(L,KS)/Z(I,KS)**2
  100 RETURN
      END
```

```
      FUNCTION CFDD(NN1,L,KS)
C
C --- THESE ARE SECOND PARTIAL D CROSS D DERIVATIVES WHICH DID NOT
C --- APPEAR IN RAC-CR-43 BUT ARE DESCRIBED IN THE PRESENT REPORT ------
C
      COMMON/SHARE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
      COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IEO,IEN
     1,IEU,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NOEFS,NCOFFS,NA,NU1,NU2,NU3
     2,I81,ND ,NU4,NU5,NU6,NU7,NU8,ND1,ND2
      COMMON/TWO/AA(6),AAB(2),FPOP(6),FPOPB(2),DL(9,7),ENL(10),RB(10),
     1EKB(10),TITLE2(10),P(15,7) ,AB(10,15),B(2,10),DB(2,10),EM(15),
     2E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),UU(15)
      COMMON/THREE/PREFER,PREFIN,PREINC,PRERET,B1(9,5),RD(5)
      COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
      COMMON/FIVE/XX(9,15),D(9,7),EN(10),Q(9,5),U(9,7)
      COMMON/SIX/Z(9,7) ,ZB(2,10),F(9,15),S(10),FB(2,10),BETA(6),Y(6),
     1BETAB(2),YB(2),BETB,BET
      COMMON/SEVEN/CFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DBX(6,15),
     1DYD(6,7),CBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
      COMMON/EIGHT/CSX(5,6),DSD(5,7),        DF1X(10,5,6),DF2X(10,5,6),
     1DF1D(10,5,7),DF2D(10,5,7),             DYBX(2,5,6),DYBD(2,5,7)
      COMMON/NINE/DBBX(5,6),DBBD(5,7)
      COMMON/ELEVEN/DBXX(90,15),DBXD(90,7),DBDD(30,5)
      COMMON/TWELVE/DSXX(30,6),DSXD(30,7),DSDD(6,5)
      COMMON/FOURTN/DBPXX(30,30),DBBXD(30,35),DBBDD(30,30),D2YB(2)
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.0) GO TO 100
      IF(NN1-NIIJ)8,8,7
    7 J=NJ + (NN1-NIIJ-1)/NI2 + 1
      I=NI + (NN1-NIIJ) - (J-NJ-1)*NI2
      GO TO 9
    8 J=(NN1-1)/NII+1
      I=NN1-(J-1)*NII
    9 DFDD            = F(I,J)*C(J,L)*C(J,KS) / (Z(I,L)*Z(I,KS))
  100 RETURN
      END
```

```
      FUNCTION DFBXX(NN1,NN2,NN3)
C
C --- THESE COMPUTIONS ARE THE SAME AS THOSE DESCRIBED IN RAC-CR-43 PART
C --- IV-B.    WITH EXCEPTIONS AS NOTED IN THE COMMENT CARDS -------
C
      COMMON/SHARE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
      COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IED,IEN
     1,IEU,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NCOFFS,NN,NU1,NU2,NU3
     2,IB1,ND ,NU4,NU5,NU6,NU7,NU8,NC1,ND2
      COMMON/TWO/AA(6),AAB(2),FPOF(6),FPOFB(2),DL(9,7),ENL(10),RB(10),
     1EKB(10),TITLE2(10),P(15,7) ,AB(10,15),B(2,10),DB(2,10),EM(15),
     2E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),UU(15)
      COMMON/THREE/PREFER,PREFIN,PREINC,PREBET,B1(9,5),RD(5)
      COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
      COMMON/FIVE/XX(9,15),D(9,7),EN(10),Q(9,5),U(9,7)
      COMMON/SIX/Z(9,7) ,ZB(2,10),F(9,15),S(10),FB(2,10),BETA(6),Y(6),
     1BETAB(2),YB(2),BETB,BET
      COMMON/SEVEN/DFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DBX(6,15),
     1DYD(6,7),DBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
      COMMON/EIGHT/DSX(5,6),DSD(5,7),        DF1X(10,5,6),DF2X(10,5,6),
     1DF1D(10,5,7),DF2D(10,5,7),             DYBX(2,5,6),DYBD(2,5,7)
      COMMON/NINE/DBBX(5,6),DBBD(5,7)
      COMMON/ELEVEN/DBXX(90,15),DBXD(90,7),DBDD(30,5)
      COMMON/TWELVE/DSXX(30,6),DSXD(30,7),DSDD(6,5)
      COMMON/FOURTN/DBBXX(30,30),DBBXD(30,35),DBBDD(30,30),D2YB(2)
      L=(NN1-1)/NM+1
      M=NN1-(L-1)*NM
      J=(NN2-1)/NI+1
      I=NN2-(J-1)*NI
      KR=(NN3-1)/NI+1
      K=NN3-(KR-1)*NI
      SUM1=0.
      SUM2=0.
      DO 10 N=1,NN
      TERM=CB(M,N)*DB(L,N)*AB(I,N)
      SUM1=SUM1+TERM/ZB(L,N)**2
   10 SUM2=SUM2+TERM*AB(K,N)/ZB(L,N)**3
      TERML=DF1X(M,K,KR)
      IF(L.EQ.2)TERML=DF2X(M,K,KR)
      TERM1=-TERML*DSX(I,J)*EN(I)*SUM1
      TERM2=0.
      IF(I.EQ.K)TERM2=-FB(L,M)*DSXX(NN2,KR)*EN(I)*SUM1
      TERM3=2.*FPOFB(L)*EN(I)*EN(K)*DSX(I,J)*DSX(K,KR)*FB(L,M)*SUM2
      DFBXX=FPOFB(L)*(TERM1+TERM2+TERM3)
      RETURN
      END
```

```
      FUNCTION DFBXD(NN1,NN2,NN3)
C
C --- THESE COMPUTIONS ARE THE SAME AS THOSE DESCRIBED IN RAC-CR-43 PART
C --- IV-B.    WITH EXCEPTIONS AS NOTED IN THE COMMENT CARDS -------
C
      COMMON/SHARE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
      COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IED,IEN
     1,IEU,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NCOFFS,NA,NU1,NU2,NU3
     2,I81,ND ,NU4,NU5,NU6,NU7,NU8,ND1,ND2
      COMMON/TWO/AA(6),AAB(2),FPOP(6),FPOPB(2),DL(9,7),ENL(10),RB(10),
     1EKB(10),TITLE2(10),P(15,7) ,AB(10,15),B(2,10),DB(2,10),EM(15),
     2E(15),FK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),UU(15)
      COMMON/THREE/PREFFR,PREFIN,PREINC,PREBET,B1(9,5),RD(5)
      COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
      COMMON/FIVE/XX(9,15),D(9,7),EN(10),Q(9,5),U(9,7)
      COMMON/SIX/Z(9,7) ,ZB(2,10),F(9,15),S(10),FB(2,10),BETA(6),Y(6),
     1BETAB(2),YB(2),BETB,BET
      COMMON/SEVEN/DFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DBX(6,15),
     1DYD(6,7),DBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
      COMMON/EIGHT/DSX(5,6),DSD(5,7),        DF1X(10,5,6),DF2X(10,5,6),
     1DF1D(10,5,7),DF2D(10,5,7),             DYBX(2,5,6),DYBD(2,5,7)
      COMMON/NINE/DBBX(5,6),DBBD(5,7)
      COMMON/ELEVEN/DBXX(90,15),DBXD(90,7),DBDD(30,5)
      COMMON/TWELVE/DSXX(30,6),DSXD(30,7),DSDD(6,5)
      COMMON/FOURTN/DBBXX(30,30),DBBXD(30,35),DBBDD(30,30),D2YB(2)
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(NC.LE.0) GO TO 100
      L=(NN1-1)/NM+1
      M=NN1-(L-1)*NM
      J=(NN2-1)/NI+1
      I=NN2-(J-1)*NI
C
C --- ND REPLACES NK IN EQUIVALENT INSTRUCTION OF RAC-CR-43 PART IV-B.
C
      K= (NN3 - 1) / ND + 1
C
C --- ND REPLACES NK IN EQUIVALENT INSTRUCTION OF RAC-CR-43 PART IV-B.
C
      KR = NN3 - (K-1) * ND
      SUM1=0.
      SUM2=0.
      DO 30 N=1,NN
      TERM=CB(M,N)*DB(L,N)*AB(I,N)
      SUM1=SUM1+TERM/ZB(L,N)**2
   30 SUM2=SUM2+TERM*AB(K,N)/ZB(L,N)**3
      TERML=DF1D(M,K,KR)
      IF(L.EQ.2)TERML=DF2D(M,K,KR)
      TERM1=TERML*DSX(I,J)*EN(I)*SUM1
      TERM2=0.
      IF(I.EQ.K)TERM2=FB(L,M)*DSXD(NN2,KR)*EN(I)*SUM1
      TERM3=-2.*FB(L,M)*EN(I)*EN(K)*DSX(I,J)*DSD(K,KR)*FPOPB(L)*SUM2
      DFBXD=-FPOPB(L)*(TERM1+TERM2+TERM3)
  100 RETURN
      END
```

```
      FUNCTION DF8DD(NN1,NN2,NN3)
C
C --- THESE ARE SECOND PARTIAL D CROSS D DERIVATIVES WHICH DID NOT
C --- APPEAR IN RAC-CR-43 BUT ARE DESCRIBED IN THE PRESENT REPORT -------
C
      COMMON/SHARE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
      COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IED,IEN
     1,IEU,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NCOFFS,NN,NU1,NU2,NU3
     2,IB1,ND ,NU4,NU5,NU6,NU7,NU8,ND1,ND2
      COMMON/TWO/AA(6),AAB(2),FPOP(6),FPOPB(2),DL(9,7),ENL(10),RB(10),
     1EKB(10),TITLE2(10),P(15,7) ,AB(10,15),B(2,10),DB(2,10),EM(15),
     2E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),UU(15)
      COMMON/THREE/PREFER,PREFIN,PREINC,PREBET,B1(9,5),RD(5)
      COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
      COMMON/FIVE/XX(9,15),D(9,7),EN(10),C(9,5),U(9,7)
      COMMON/SIX/Z(9,7) ,ZB(2,10),F(9,15),S(10),FB(2,10),BETA(6),Y(6),
     1BETAB(2),YB(2),BETB,BET
      COMMON/SEVEN/DFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DBX(6,15),
     1DYD(6,7),DBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
      COMMON/EIGHT/DSX(5,6),DSD(5,7),        DF1X(10,5,6),DF2X(10,5,6),
     1DF1D(10,5,7),DF2D(10,5,7),             DYBX(2,5,6),DYBD(2,5,7)
      COMMON/NINE/DBBX(5,6),DBBD(5,7)
      COMMON/ELEVEN/DBXX(90,15),DBXD(90,7),DBDD(30,5)
      COMMON/TWELVE/DSXX(30,6),DSXD(30,7),DSDD(6,5)
      COMMON/FOURTN/DBBXX(30,30),DBBXD(30,35),DBEDD(30,30),D2YB(2)
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.0) GO TO 100
      L=(NN1-1)/NM+1
      M=NN1-(L-1)*NM
      I = ( NN2 - 1) / ND + 1
      J = NN2 - ( I - 1 ) * ND
      K= (NN3 - 1) / ND + 1
      KR = NN3 - (K-1) * ND
      SUM1=0.
      SUM2=0.
      DO 30 N=1,NN
      TERM=CB(M,N)*DB(L,N)*AB(I,N)
      SUM1=SUM1+TERM/ZB(L,N)**2
   30 SUM2=SUM2+TERM*AB(K,N)/ZB(L,N)**3
      TERML=DF1D(M,K,KR)
      IF(L.EQ.2)TERML=DF2D(M,K,KR)
      TERM1=TERML*DSD(I,J)*EN(I)*SUM1
      TERM2=0.
      IF(I.EQ.K)TERM2=FB(L,M)*DSDD(NN2,KR)*EN(I)*SUM1
      TERM3=-2.*FB(L,M)*EN(I)*EN(K)*DSD(I,J)*DSD(K,KR)*FPOPB(L)*SUM2
      DF8DD=-FPOPB(L)*(TERM1+TERM2+TERM3)
  100 RETURN
      END
```

```
      SUBROUTINE STARTP
C
C *** THIS SUBROUTINE SELECTS A STARTING FEASIBLE POINT. CALLED IF NU1=1
C
      COMMON/SHAPE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
      COMMON/ONE/NT,NJ,NTI,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IFX,IFD,IEN
     1,IEU,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NODEFS,NN,NU1,NU2,NU3
     2,IB1,ND ,NU4,NU5,NU6,NU7,NU8,ND1,ND2
      COMMON/TWO/AA(6),AAB(2),FPOP(5),FPOPB(2),DL(9,7),ENL(10),PB(10),
     1FKD(10),TITLE2(10),P(15,7) ,AB(10,15),B(2,10),DB(2,10),EM(15),
     2E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),UU(15)
      COMMON/THREE/PREFER,PREFIN,PREINC,PREBET,B1(9,5),BD(5)
      COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
      COMMON/FIVE/XX(9,15),D(9,7),FN(10),Q(9,5),U(9,7)
      COMMON/SIX/Z(9,7) ,ZB(2,10),F(9,15),S(10),FB(2,10),BETA(6),Y(6),
     1BETAP(2),YB(2),BETB,BET
      COMMON/SEVEN/DFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DBX(6,15),
     1DYD(6,7),DBD(6,7),BETPP(2),BETPP(6),BETPP2(2)
      COMMON/EIGHT/DSX(5,6),DSD(5,7),          DF1X(10,5,6),DF2X(10,5,6),
     1DF1D(10,5,7),DF2D(10,5,7),              DYBX(2,5,6),DYBD(2,5,7)
      COMMON/NINE/DBBX(5,6),DBBD(5,7)
      COMMON /OUTIN/ BBP(20),ZN1(20),ZN2(20),RAT(10)
      COMMON /EQAL/ H,H1,M7
      DIMENSION ALL(20)
      CV = PREBET/(PREFER + PREBET)
      CF = 1. - CV
      SMALL=.01
      FL1 = FLOAT(NTI)/FLOAT(NII+1)
      FL2 = FLOAT(NI2) / FLOAT(NI2 + 1)
      DO 10 J=1,NJ
   10 ALL(J) = FL1 * EM(J)
      DO 20 I=NI1,NII
      DO 20 J=NJ1,NJJ
   20 XX(I,J) = EM(J) * FL2 * FPOP(I-NI) + SMALL
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.0) GO TO 500
      IF(ND2.EQ.2) GO TO 200
      GO TO (30,40,50,60),ND1
   30 SUM=0.0
      DO 36 K=1,ND
      ALL(K) = ALL(K) /2.0
      DO 32 I=1,NI
   32 U(I,K) =  CF *  ALL(K) /   FLOAT(NT) + SMALL
      DO 34 I=NI1,NII
   34 U(I,K) =  CV *  ALL(K) * FPOP(I-NI)  + SMALL
   36 CONTINUE
      GO TO 500
   40 ALL(1) = ALL(1) / 3.0
      ALL(2) = ALL(2) / 2.0
      ALL(3) = ALL(3) / 2.0
      DO 46 J=1,2
      DO 42 I=1,NT
   42 U(I,J) =  ALL(1) * CF /  FLOAT(NI)  + SMALL
      DO 44 I=NI1,NII
   44 U(I,J) =  ALL(1) * CV * FPOP(I-NI)
```

```
   46 CONTINUE
      DO 47 I=1,NI
      U(I,3) = ALL(2) * CF /  FLOAT(NT)    + SMALL
   47 U(I,4) = ALL(3) * CF /  FLOAT(NI)    + SMALL
      DO 48 I=NI1,NII
      U(I,3)= ALL(2) * CV *  EPOP(I-NI)    + SMALL
   48 U(I,4)= ALL(3) * CV *  EPOP(I-NI)    + SMALL
      GO TO 500
   50 ALL(1)= ALL(1)/ 4.0
      ALL(2)= ALL(2)/ 2.0
      DO 56 J=1,3
      DO 52 I=1,NT
   52 U(I,J)= ALL(1)  * CF / FLOAT(NI)  + SMALL
      DO 54 I=NI1,NII
   54 U(I,J) = ALL(1) * CV * EPOP(I-NI) +SMALL
   56 CONTINUE
      DO 57 I=1,NT
   57 U(I,4) = ALL(2) * CF / FLOAT(NI)    + SMALL
      DO 58 I=NI1,NII
   58 U(I,4)= ALL(2) * CV * EPOP(I-NI)  + SMALL
      GO TO 500
   60 ALL(1)= ALL(1) / 5.0
      DO 66 J=1,ND
      DO 62 I=1,NT
   62 U(I,J)= ALL(1) * CF / FLOAT(NI) + SMALL
      DO 64 I=NI1,NII
   64 U(I,J)= ALL(1) * CV * EPOP(I-NI) + SMALL
   66 CONTINUE
      GO TO 500
  200 ALL(1) = ALL(1) / 3.0
      ALL(2) = ALL(2) / 3.0
      K=1
      DO 210 J=1,4
      IF(J.GT.2) K=2
      DO 202 I=1,NT
  202 U(I,J) = ALL(K) * CF / FLOAT(NT)  + SMALL
      DO 204 I=NT1,NI2
  204 U(I,J) = ALL(K) * CV * EPOP(I-NI) + SMALL
  210 CONTINUE
  500 DO 600 J= 1,NJ
      DO 525 I= 1,NT
  525 XX(I,J)= CF * ALL(J) / FLOAT(NI) + SMALL
      DO 550 I=NI1,NII
  550 XX(I,J)= CV * ALL(J) * EPOP(I-NI)  + SMALL
  600 CONTINUE
      DO 710 I=1,NII
      DO 710 J=1,NJ
      N=(J-1)*NII + I
  710 Y(N)= XX(I,J)
      DO 719 J=1,NJ2
      DO 711 I=1,NI2
      N= NII(J + (J-1)* NI2 + I
  711 Y(N)=XX(NI+I,NJ+J)
C
C --- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------
C
      IF(ND.LE.0.0) GO TO 1000
      DO 720 I=1,NII
```

```
      DO 720 K=1,ND
      N= IEX + (I-1)*ND + K
  720 X(N)= U(I,K)
 1000 RETURN
      END
```

```
      SUBROUTINE READOU (KT)                                            14750
C
C --- THIS SUBROUTINE SUMMARIZES THE RESULTS OF AN EXCHANGE -----
C
      COMMON/SHARE/ X(100), DEL(100), A(100,100),NV,MC,MN,NP1,NM1
      COMMON/ONE/NI,NJ,NII,NJJ,NM,NK,NL,NI1,NJ1,NI2,NJ2,NIIJ,IEX,IED,IEN
     1,IEU,IEX1,IEXEN,I1,I2,I3,I4,I5,I6,I7,NDEFS,NCOFFS,NA,NU1,NU2,NU3
     2,I01,ND ,NU4,NU5,NU6,NU7,NU8,ND1,ND2
      COMMON/TWO/AA(6),AAB(2),FFOP(6),FFOPB(2),DL(9,7),ENL(10),RB(10),
     1EKB(10),TITLE2(10),P(15,7) ,AB(10,15),B(2,10),DE(2,10),EM(15),
     2E(15),EK(15),TITLE1(15),PB(10,15),AN(15,7),SS(5,6),UU(15)
      COMMON/THREE/PREFER,PREFIN,PREINC,PREBET,B1(9,5),RD(5)
      COMMON/FOUR/ C(15,7),CB(10,15),ELNS(5,6)
      COMMON/FIVE/XX(9,15),D(9,7),EN(10),Q(9,5),U(9,7)
      COMMON/SIX/Z(9,7) ,ZB(2,10),F(9,15),S(10),FB(2,10),EETA(6),Y(6),
     1BETAB(2),YB(2),BETB,BET
      COMMON/SEVEN/DFX(9,15,15),DFD(9,15,7),BETP(6),DYX(6,15),DBX(6,15),
     1DYD(5,7),DBD(6,7),BETBP(2),BETPP(6),BETBPP(2)
      COMMON/EIGHT/DSX(5,6),DSD(5,7),        DF1X(10,5,6),DF2X(10,5,6),
     1DF1D(10,5,7),DF2D(10,5,7),            DYBX(2,5,6),DYBD(2,5,7)
      COMMON/NINE/DBBX(5,6),DBBD(5,7)
      COMMON /OUTIN/ RBB(20),ZN1(20),ZN2(20),RAT(10)
      DIMENSION X1(20),X2(20),X3(20),X4(20),X5(20),X6(20)
      WRITE (6,655)
      WRITE (6,660)
      CALL IDENTV
      CALL FRACTS
  950 FORMAT( //10X, 30H***** DAMAGE TO SIDE ONE *****,F5.3)
  955 FORMAT( //10X, 30H***** DAMAGE TO SIDE TWO *****,F5.3)
      WRITE (6,405)                                                     15400
      WRITE(6,950)BETB
      WRITE(6,955)BET
      WRITE (6,410)                                                     15405
      WRITE (6,490)                                                     15905
      WRITE(6,825)(TITLE1(J),J=1,NJ)
      DO 855 I=1,NI
      DO 840 J=1,NJ
      X1(J) = XX(I,J) / RBB(J)
      X2(J) = XX(I,J)
      X3(J) = X2(J) * ZN1(J)
      X4(J) = X3(J) * F(I,J)
      X5(J) = X4(J) / EN(I)
      IF(X5(J).GT.140.) X5(J)=140.
  840 X6(J) = SS(I,J) ** X5(J)
      WRITE(6,805)(X1(J),J=1,NJ)
      WRITE(6,810)(X2(J),J=1,NJ)
      WRITE(6,815)TITLE2(I),(X3(J),J=1,NJ)
      WRITE(6,810)(X4(J),J=1,NJ)
      WRITE(6,820)(X5(J),J=1,NJ)
      WRITE(6,820)(X6(J),J=1,NJ)
  855 CONTINUE
      WRITE(6,655)
      WRITE (6,540)                                                     16095
      IF(NJJ.LE.12) M1 = NJJ
      IF(NJJ.GT.12) M1 = 12
      WRITE(6,830)(TITLE1(J),J=1,M1)
      DO 896 I=1,NI2
```

```
      II= NI + I
      DO 885 J=1,M1
      X1(J) = XX(II,J) / RBB(J)
      X2(J) = XX(II,J)
      X3(J) = XX(II,J)*F(II,J)
  885 X4(J) = X3(J) *EK(J)
      WRITE(6,830)(X1(J),J=1,M1)
      WRITE(6,895) I,(X2(J),J=1,M1)
      WRITE(6,810)(X3(J),J=1,M1)
      WRITE(6,810)(X4(J),J=1,M1)
  896 CONTINUE
      IF(NJJ.LE.12) GO TO 905
      WRITE(6,825)(TITLE1(J),J=13,NJJ)
      DO 900 I=1,NI2
      DO 889 J=13,NJJ
      II = NI + I
      X1(J) = XX(II,J) / RBB(J)
      X2(J) = XX(II,J)
      X3(J) = XX(II,J)*F(II,J)
  889 X4(J) = X3(J) *EK(J)
      WRITE(6,830)(X1(J),J=13,NJJ)
      WRITE(6,895) I,(X2(J),J=13,NJJ)
      WRITE(6,810)(X3(J),J=13,NJJ)
      WRITE(6,810)(X4(J),J=13,NJJ)
  900 CONTINUE
  905 CONTINUE
      WRITE(6,655)

--- IF NO ATTACK ON DEFENSES BYPASS THIS SECTION --------

      IF(ND.LE.0) GO TO 787
      WRITE(6,575)
      WRITE(6,835) (K,K=1,ND)
      DO 780 I=1,NII
      DO 770 M=1,ND
      X1(M) = U(I,M) / RBB(M)
      X3(M) = DL(I,M)/RD(M)
      X4(M) =  C(I,M)/RD(M)
  770 X2(M) = U(I,M)
      WRITE(6,830)(X1(M),M=1,ND)
      WRITE(6,895) I,(X2(M),M=1,ND)
      WRITE(6,810)(X3(M),M=1,ND)
      WRITE(6,810)(X4(M),M=1,ND)
  780 CONTINUE
  787 CONTINUE
      WRITE(6,655)
      WRITE (6,545)
      DO 760 L=1,NL                                          162450
      DO 750 M=1,NM
      X1(M) = EN(M)
      X2(M) = EN(M)* S(M) / RR(M)
      X3(M) = X2(M) * RB(M)
      X4(M) = X3(M) * FB(L,M)
  750 X5(M) = X4(M) * EKB(M)
      WRITE(6,825)(TITLE2(M),M=1,NM)
      WRITE(6,830)(X1(M),M=1,NM)
      WRITE(6,895) L,(X2(M),M=1,NM)
      WRITE(6,810)(X3(M),M=1,NM)
```

```
      WRITE(6,810)(X4(M),M=1,NM)
      WRITE(6,810)(X5(M),M=1,NM)
  760 CONTINUE
      NU8 = NU8 + 1
      IF(NU8.GT.NU4) KT = 2
      IF(NU8.GT.NU4) RETURN
      IF(RAT(NU8 ).GT.1.E+7) PREBET=100.
      IF(RAT(NU8 ).GT.1.E+7) PREFER=0.
      IF(RAT(NU8 ).GT.1.E+7) GO TO 1000
      PREFER = 100.
      PREBET = PREFER * RAT(NU8)
  805 FORMAT (47X,30HSTRATEGIC ANALYSIS OF EXCHANGE)                    167700
  810 FORMAT (/50X,30HNEW SIDE ONE ARSENAL          )
  835 FORMAT( //10X,12(4X,I2,4X))
  875 FORMAT( 35X, 47HSIDE ONE COUNTER DEFENSE STRIKE CHARACTERISTICS/
     1  20X, 90HSIDE ONE (ALLOCATIONS) ON DEFENSES OF RESOURCE TYPE (ROW
     2S)  DEFENDED BY DFOR. TYPE (COLS.)/29X,10H(ARRIVALS)/20X,
     3       90HSIDE TWO ( ORIG. NO. ) OF DEFORS.  OF RESOURCE TYPE (ROW
     4S)  ATTACKED BY OFFS.                /20X
     5       90HSIDE TWO ( SURV. NO. ) OF DEFORS.  OF RESOURCE TYPE (ROW
     6S)  ATTACKED BY OFFS.                )
  950 FORMAT (/35X,57HAGGREGATE COUNTERVALUE DAMAGE CHARACTERISTICS OF E  168350
     1XCHANGE//45X,50HTOTAL NUMBER OF ALLOCATED (COLUMN) ON (ROW) CITIES  168400
     2/10X,18HINTERPRETATION OF ,17X,44HNUMBER OF ARRIVING (COLUMN) ON (  168450
     3ROW) CITIES /10X,20HEACH SET OF ENTRIES ,15X,38HNUMBER OF IMPACTIN  168500
     4G (COLUMN) ON (ROW) /45X,58HNUMBER OF 1 MT. EQUIVALENTS ON (ROW) C  168550
     5ITIES FROM (COLUMN) )                                               168600
  955 FORMAT (/20X,8HMISSILES,20X,7HBOMBERS,20X,5HSLBMS,20X,11HPERCENTAG  168650
     1E /75X,13HSIDE TWO ONLY,12X,6HDAMAGE)                               168700
  990 FORMAT (45X,46HSIDE ONE COUNTERFORCE STRIKE CHARACTERISTICS  //30X  169050
     1,56HMISSILES OF TYPE (COLUMN) ALLOCATED AGAINST TARGET (ROW)/30X,5  169100
     22HMISSILE OF TYPE (COLUMN) ARRIVING OVER TARGET (ROW) /5X,18HINTER  169150
     3PRETATION OF ,7X,55HWARHEADS OF MISSILE TYPE (COLUMN) ARRIVING OVE  169200
     4R TARGET /5X,20HEACH SET OF ENTRIES ,5X,60HWARHEADS OF MISSILE TYP  169250
     5E (COLUMN) IMPACTING ON TARGET (ROW) /30X,66HWARHEADS OF MISSILE T  169300
     6YPE (COLUMN) IMPACTING ON EACH MISSILE (ROW) /30X,73HSURVIVAL PROB  169350
     7. OF EACH MISSILE TYPE (ROW) FROM ATTACK BY MISSILE (COLUMN))       169400
 1035 FORMAT (//25X,67HNUMBER OF EACH SIDE TWO MISSILE TYPE SURVIVING CO  169850
     1UNTERFORCE STRIKE )                                                 169900
 1040 FORMAT (40X,46HSIDE ONE COUNTERVALUE STRIKE CHARACTERISTICS  //30X  169950
     1,61HWEAPONS OF TYPE (COLUMN) ALLOCATED AGAINST CITY CLASS (ROW)  /  170000
     26X,18HINTERPRETATION OF ,6X,56HWEAPONS OF TYPE (COLUMN) ARRIVING O  170050
     3VER CITY CLASS (ROW) /6X,20HEACH SET OF ENTRIES ,4X,48HWEAPONS OF T  170100
     4YPE (COLUMN) IMPACTING ON CITY CLASS /30X,74HNO. OF 1 MT. EQS. FRO  170150
     5M WEAPON TYPE (COLUMN) IMPACTING ON CITY CLASS (ROW) )              170200
 1045 FORMAT (41X,39HSIDE TWO SECOND STRIKE CHARACTERISTICS /30X,68HNO.   170250
     1OF SIDE TWO WEAPONS OF TYPE (COLUMN) BEFORE COUNTERFORCE STRIKE /3  170300
     20X,71HNO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) SURVIVING COUNTERFO  170350
     3RCE STRIKE /6X,18HINTERPRETATION OF ,6X,62HNO. OF SIDE TWO WEAPONS  170400
     4 OF TYPE (COLUMN) ARRIVING OVER CITIES /6X,20HEACH SET OF ENTRIES   170450
     5,4X,70HNO. OF SIDE TWO WEAPONS OF TYPE (COLUMN) IMPACTING ON SIDE   170500
     6ONE CITIES /30X,70HNO. OF 1 MT. EQS. FROM EACH WEAPON TYPE (COLUMN  170550
     7) IMPACTING ON CITIES  )                                            170600
  655 FORMAT (1H1)
  660 FORMAT (29X,62H**********STRATEGIC WEAPONS EXCHANGE MODELS (SWEM)
     1**********,//45X,34H    ALLOCATION OPTIMIZATION MODEL )
 800 FORMAT (//1X,4HCITY,5X,12(4X,A6)/1X,5HCLASS)
 805 FORMAT (/10X,12(2X,F6.1,2X))
```

```
810   FORMAT (10X,12(2X,F6.1,2X))
815   FORMAT (2X,A6,2X,12(2X,F6.1,2X))
820   FORMAT (10X,12(2X,F6.3,2X))
  825 FORMAT( //1)X,12(4X,A6))
830   FORMAT (/10X,12(2X,F6.1,2X))
895   FORMAT (4X,I2,4X,12(2X,F6.1,2X))
 1000 IF(NU1.EQ.1) CALL STARTB
      RETURN
      END                                                    170650
```

Appendix C

D CROSS D SECOND PARTIAL DERIVATIVES

Appendix C

D CROSS D SECOND PARTIAL DERIVATIVES

These derivatives are used in the allocation model for attacks on defenses and were not documented in RAC-CR-43.

$$\frac{\partial^2 F_{ij}}{\partial d_{ir}\,\partial d_{ik}} = F_{ij}\,\frac{C_{jr}}{Z_{ir}}\,\frac{C_{jk}}{Z_{ik}} \qquad (l = 1,\ldots,II) \quad (j = 1,\ldots,D) \quad (k = 1,\ldots,D) \quad (n - 1,\ldots,D)$$

$$\frac{\partial^2 \beta}{\partial d_{I+ir}\,\partial d_{I+ik}} = P_i\left(\frac{d^2\beta_i}{dy_1^2}\,\frac{\partial y_i}{\partial d_{I+ir}}\,\frac{\partial y_i}{\partial d_{I+ik}} + \frac{d\beta_i}{dy_i}\,\frac{\partial^2 y_i}{\partial d_{I+ir}\,\partial d_{I+ik}}\right)$$

where

$$\frac{\partial^2 y_i}{\partial d_{I+ir}\,\partial d_{I+ik}} = \sum_{j=1}^{JJ}\left(\frac{\partial^2 F_{I+ij}}{\partial d_{I+ir}\,\partial d_{I+ik}}\,x_{I+ij}\,k_j\right)$$

$$\frac{\partial^2 S_n}{\partial d_{nr}\,\partial d_{nk}} = \begin{cases} \dfrac{\partial S_n}{\partial d_{nr}}\,\dfrac{1}{S_n}\,\dfrac{\partial S_n}{\partial d_{nk}} + \dfrac{S_n}{n_n}\left(\sum_{j=1}^{J} x_{nj}\,\dfrac{\partial^2 F_{nj}}{\partial d_{nr}\,\partial d_{nk}}\,e_j\,\ell_n S_{nj}\right) & \text{if } S_n \neq 0 \\ 0 & \text{if } S_n = 0 \end{cases}$$

$$\frac{\partial^2 \bar{F}_{in}}{\partial d_{re}\,\partial d_{ik}} = -\bar{P}(\ell)\left\{\begin{array}{l} \dfrac{\partial \bar{F}_{in}}{\partial d_{re}}\,\dfrac{\partial S_i}{\partial d_{ik}}\,n_i\left(\sum_{n=1}^{N}\dfrac{\bar{c}_{nn}\,\bar{d}_{in}\,\bar{a}_{in}}{\bar{Z}_{in}^2}\right) \\ + \bar{F}_{in}\,\dfrac{\partial^2 S_i}{\partial d_{re}\,\partial d_{ik}}\,n_i \quad \text{(sum above)} \\ + \bar{F}_{in}\,\dfrac{\partial S_i}{\partial d_{ik}}\,n_i\left(\sum_{n=1}^{N}\dfrac{\bar{c}_{nn}\,\bar{d}_{in}\,\bar{a}_{in}\,\bar{a}_{rn}}{\bar{Z}_{in}^3}\right)\left(-2\bar{P}(\ell)\,\dfrac{\partial S_r}{\partial d_{re}}\,n_r\right) \end{array}\right.$$

RAC

$$\frac{\partial^2 \bar{\beta}}{\partial d_{rs}\, \partial d_{ik}} = \sum_{\ell=1}^{L} \bar{P}(\ell) \left(\frac{d^2 \bar{\beta}_\ell}{d\bar{y}^2_\ell} \frac{\partial \bar{y}_\ell}{\partial d_{rs}} \frac{\partial \bar{y}_\ell}{\partial d_{ik}} + \frac{d\bar{\beta}_\ell}{d\bar{y}_\ell} \frac{\partial^2 \bar{y}_\ell}{\partial d_{rs}\, \partial d_{ik}} \right)$$

where

$$\frac{\partial^2 \bar{y}_\ell}{\partial d_{rs}\, \partial d_{ik}} = \bar{P}(\ell) \left\{ \sum_{m=1}^{M} \left(\frac{\partial \bar{F}_{\ell m}}{\partial d_{rs}\, \partial d_{ik}} S_m n_m \bar{K}_m \right) + \frac{\partial \bar{F}_{\ell r}}{\partial d_{ik}} \frac{\partial S_r}{\partial d_{rs}} n_r \bar{K}_r \right.$$

$$\left. + \frac{\partial \bar{F}_{\ell i}}{\partial d_{rs}} \frac{\partial S_i}{\partial d_{ik}} n_i \bar{K}_i + \bar{F}_{\ell i} \frac{\partial^2 S_i}{\partial d_{rs}\, \partial d_{ik}} n_i \bar{K}_i \delta_{ir} \right\}$$

Appendix D

PARTIAL GLOSSARY OF MODEL NOTATION AND FORTRAN NOTATION

Appendix D

PARTIAL GLOSSARY OF MODEL NOTATION AND FORTRAN NOTATION

Independent Variables and Computed Functions

MODEL NOTATION	FORTRAN NOTATION
x_{ij}	XX(I,J)
u_{ik}	U(I,K)
d_{ik}	D(I,K)
d'_{ik}	DL(I,K)
n_i	EN(I)
F_{ij}	F(I,J)
z_{ik}	Z(I,K)
s_i	S(I)
$\bar{z}_{\ell n}$	ZB(L,N)
$\bar{F}_{\ell m}$	FB(L,M)
y_i	Y(I)
β_i	BETA(I)
β	BET
$\bar{y}_\ell$	YB(L)
$\bar{\beta}_\ell$	BETAB(L)
$\bar{\beta}$	BETB
P_i	FPOP(I)
$\bar{P}_\ell$	FPOPB(L)

MODEL NOTATION	FORTRAN NOTATION
$\frac{\partial \bar{y}_\ell}{\partial d_{ik}}$	DYBD(L,I,K)
$\frac{d\bar{\beta}_\ell}{d\bar{V}_\ell}$	BETBP(L)
$\frac{\partial \bar{\beta}}{\partial X_{ij}}$	DBBX(I,J)
$\frac{\partial \bar{\beta}}{\partial d_{ik}}$	DBBD(I,K)
$\frac{\partial^2 F_{ij}}{\partial X_{is}\ \partial X_{i\ell}}$	DFXX(NN1,L,KS) NN1 depends on i and j
$\frac{\partial^2 F_{ij}}{\partial d_{is}\ \partial X_{i\ell}}$	DFXD(NN1,L,KS) NN1 depends on i and j
$\frac{\partial^2 \beta}{\partial X_{i+1,r}\ \partial X_{i+1,j}}$	DBXX(NN2,KR) NN2 depends on i and j
$\frac{\partial^2 \beta}{\partial d_{i+1,r}\ \partial X_{i+1,j}}$	DBXD(NN2,KR) NN2 depends on i and j
$\frac{\partial^2 S_n}{\partial X_{m\ell}\ \partial X_{mk}}$	DSXX(NN2,L) NN2 depends on m and k
$\frac{\partial^2 S_n}{\partial d_{m\ell}\ \partial X_{mk}}$	DSXD(NN2,L) NN2 depends on m and k
$\frac{\partial F_{ij}}{\partial X_{i\ell}}$	DFX(I,J,L)
$\frac{\partial F_{ij}}{\partial d_{ik}}$	DFD(I,J,K)

MODEL NOTATION	FORTRAN NOTATION
$\frac{\partial \beta}{\partial X_{i+1,j}}$	DBX(I,J)
$\frac{\partial y_i}{\partial X_{i+1,j}}$	DYX(I,J)
$\frac{\partial \beta}{\partial d_{i+1,k}}$	DBD(I,K)
$\frac{\partial y_i}{\partial d_{i+1,k}}$	DYD(I,K)
$\frac{\partial S_m}{\partial X_{\cdot,j}}$	DSX(M,J)
$\frac{\partial S_m}{\partial d_{mk}}$	DSD(M,K)
$\frac{d\beta_i}{dy_i}$	BETP(I)
$\frac{\partial \bar{F}_{\ell m}}{\partial X_{ij}}$	DF1X(M,I,J) if ℓ=1 DF2X(M,I,J) if ℓ=2
$\frac{\partial \bar{F}_{\ell m}}{\partial d_{ik}}$	DF1D(M,I,K) if ℓ=1 DF2D(M,I,K) if ℓ=2
$\frac{\partial \bar{y}_\ell}{\partial X_{ij}}$	DYBX(L,I,J)
$\frac{\partial^2 \bar{F}_{\ell m}}{\partial X_{kr}\ \partial X_{ij}}$	DFBXX(NN1,NN2,NN3) NN1 depends on ℓ and m NN2 depends on i and j NN3 depends on k and r

MODEL NOTATION	FORTRAN NOTATION
$\frac{\partial^2 \overline{F}_{\ell m}}{\partial d_{kr}\, \partial X_{ij}}$	DFBXD(NN1,NN2,NN3) NN1 depends on ℓ and m NN2 depends on i and j NN3 depends on k and r
$\frac{\partial^2 \overline{\beta}}{\partial x_{kr}\, \partial x_{ij}}$	DBBXX(NN1,NN2) NN1 depends on i and j NN2 depends on k and r
$\frac{\partial^2 \overline{\beta}}{\partial d_{kr}\, \partial x_{ij}}$	DBBXD(NN1,NN2) NN1 depends on i and j NN2 depends on k and r
$\frac{\partial^2 F_{ij}}{\partial d_{is}\, \partial d_{i\ell}}$	DFDD (NN1,L,KS) NN1 depends on i and j
$\frac{\partial^2 \beta}{\partial d_{I+ir}\, \partial d_{I+ij}}$	DBDD (NN2,KR) NN2 depends on i and j
$\frac{\partial^2 S_m}{\partial d_{mj}\, \partial d_{mk}}$	DSDD (NN2,L) NN2 depends on m and k
$\frac{\partial^2 \overline{F}_{\ell m}}{\partial d_{kr}\, \partial d_{ij}}$	DFBDD (NN1, NN2, NN3) NN1 depends on ℓ and m NN2 depends on i and j NN3 depends on k and r
$\frac{\partial^2 \overline{\beta}}{\partial d_{kr}\, \partial d_{ij}}$	DBBDD (NN1, NN2) NN1 depends on ℓ and m NN2 depends on k and r